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Lowe et al.

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(54) **WEARABLE DEVICE ASSEMBLY HAVING ANTENNA**

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G08C 19/16 (2006.01)
H05K 7/06 (2006.01)
(Continued)

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CPC ***H01Q 1/273*** (2013.01); ***A61B 5/0022*** (2013.01); ***A61B 5/02055*** (2013.01); ***A61B 5/11*** (2013.01); ***A61B 5/681*** (2013.01); ***A63B 24/0062*** (2013.01); ***G08C 19/16*** (2013.01); ***H04Q 9/00*** (2013.01); ***H05K 1/0281*** (2013.01); ***H05K 1/189*** (2013.01); ***H05K 7/06*** (2013.01); *A63B 2220/40* (2013.01); *A63B 2220/836* (2013.01); *A63B 2225/50* (2013.01); *H04Q 2209/30* (2013.01); *H04Q 2209/43* (2013.01); *H04Q 2209/823* (2013.01); *H05K 2201/10098* (2013.01); *H05K 2201/10151* (2013.01)

(58) **Field of Classification Search**
USPC 361/749; 340/870.02; 343/718
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,366,250	B1	4/2002	McConnell
6,513,532	B2	2/2003	Mault et al.

(Continued)

FOREIGN PATENT DOCUMENTS

DE	10 2010 000 778		7/2011
GB	2280065	A	1/1995

(Continued)

OTHER PUBLICATIONS

PCT/US2013/022232 Written Opinion mailed Mar. 25, 2013, PCT European Patent Office.

(Continued)

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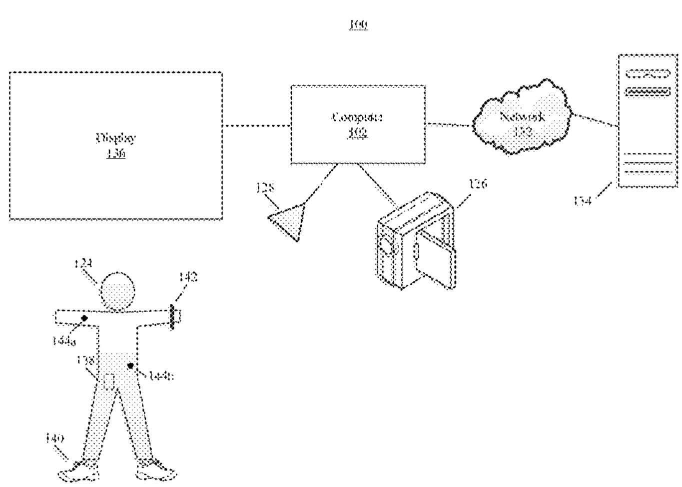
(57) **ABSTRACT**

A wrist-worn device monitors movements of a user. A sensor assembly of the wrist-worn device is configured to detect movement of the user and generate sensor data based on the movement detected. A controller connected to the sensor assembly obtains movement data based on the sensor data. An antenna connected to the controller is configured to operate at a desired frequency when a wrist of the user is received by the device such that the movement data is wirelessly transmittable from the wrist-worn device to an electronic device. The antenna may exhibit a different design and configuration depending on the size of the wrist-worn device.

18 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

A63B 24/00	(2006.01)
H05K 1/02	(2006.01)
H05K 1/18	(2006.01)
A61B 5/00	(2006.01)
A61B 5/0205	(2006.01)
A61B 5/11	(2006.01)
H04Q 9/00	(2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0012194	A1	1/2005	Jaeck
2007/0021269	A1	1/2007	Shum
2009/0284937	A1	11/2009	Rytky
2012/0253485	A1	10/2012	Weast et al.

FOREIGN PATENT DOCUMENTS

JP	03088404		12/1991
JP	09036630		7/1997
WO	2010126821	A1	11/2010

OTHER PUBLICATIONS

PCT/US2013/022232 International Search Report mailed Mar. 25, 2013, PCT European Patent Office.

Apr. 9, 2013—(WO) Written Opinion—App. No. PCT/US2013/022196.

Apr. 9, 2013—(WO) International Search Report—App. No. PCT/US2013/022196.

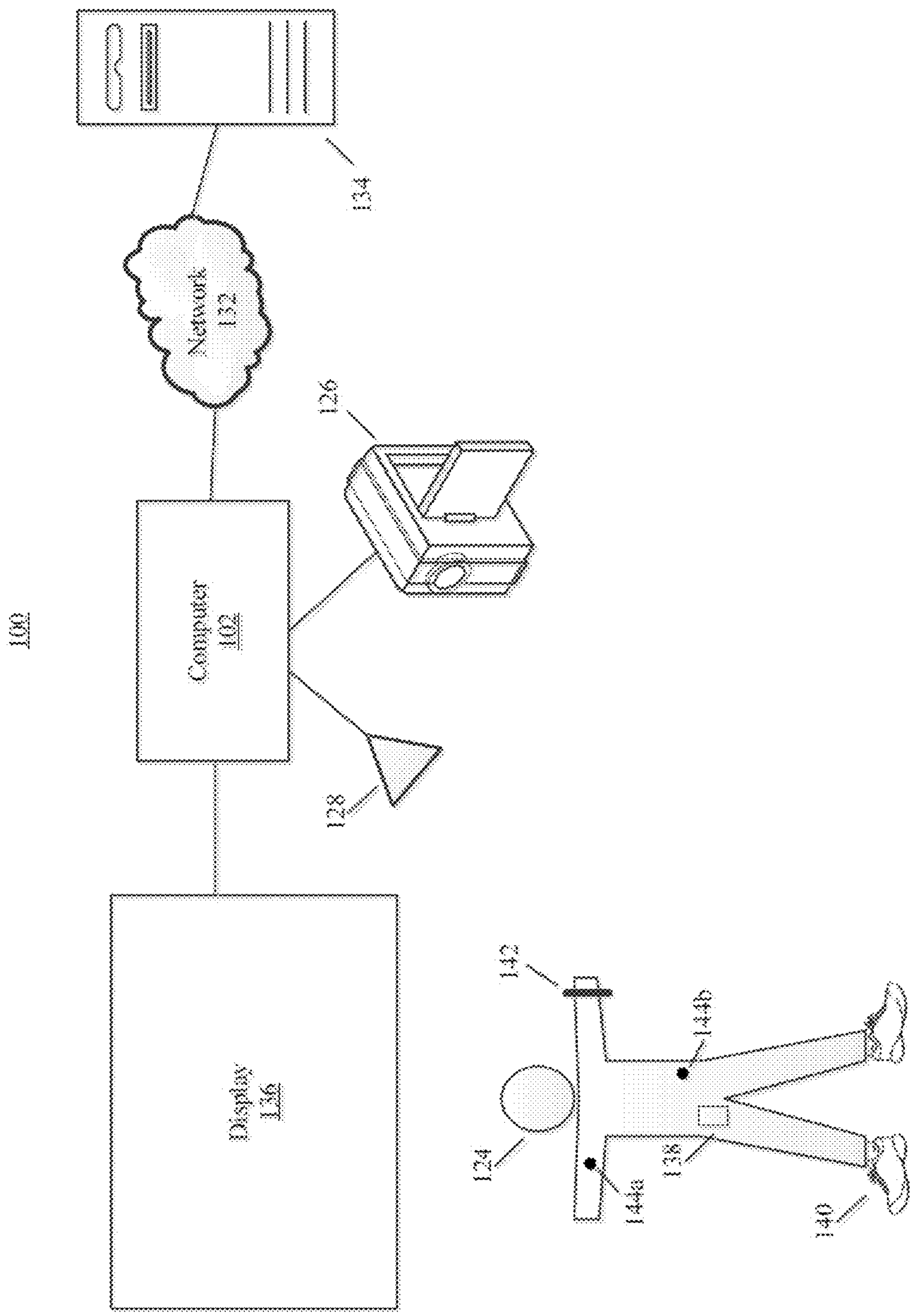

100
Computer
102
Network
132
134
126
128
Display
136
142
144b
124
144a
138
140

FIG. 1

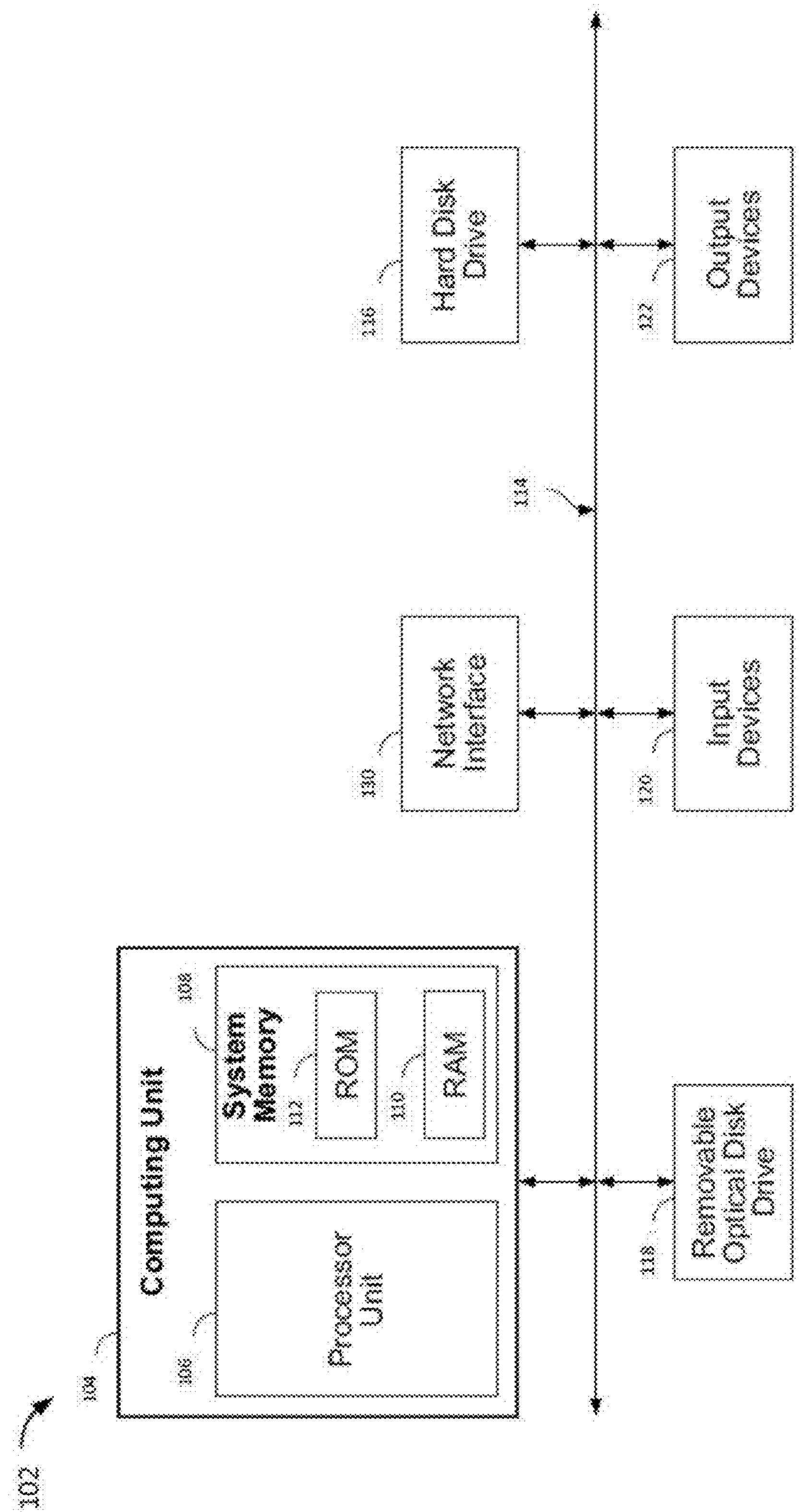

102
104
Computing Unit
106
Processor Unit
108
System Memory
112
ROM
110
RAM
114
116
Hard Disk Drive
130
Network Interface
118
Removable Optical Disk Drive
120
Input Devices
122
Output Devices

FIG. 2

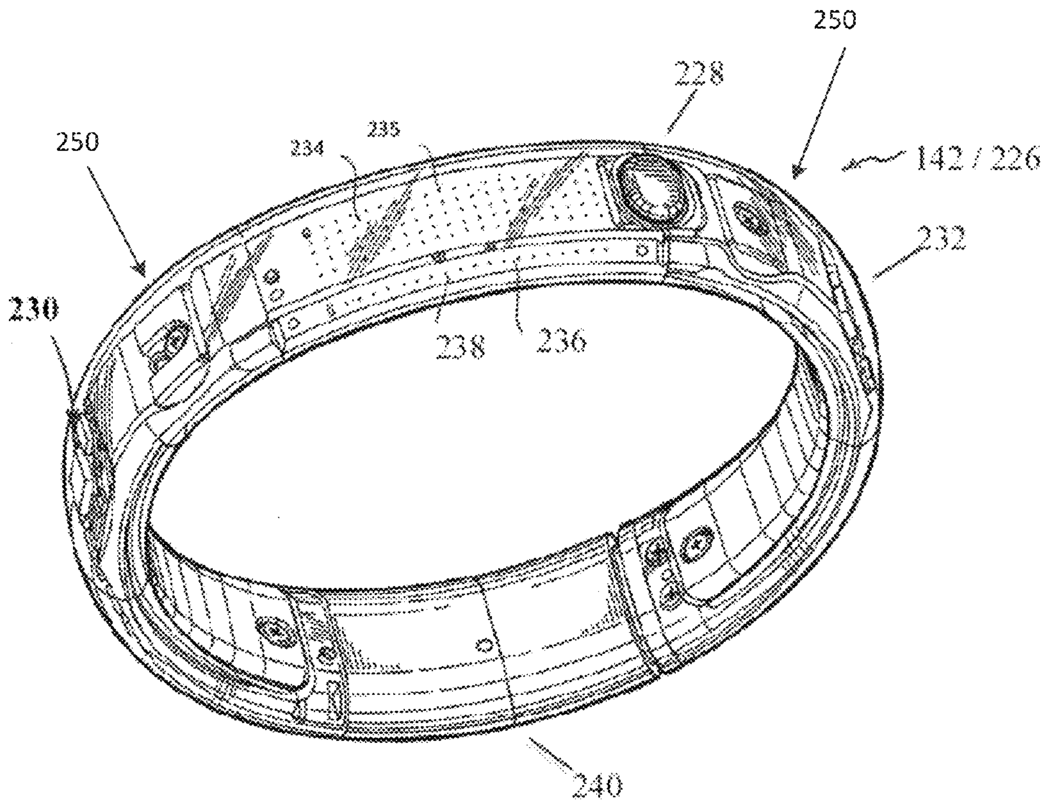


FIG. 3

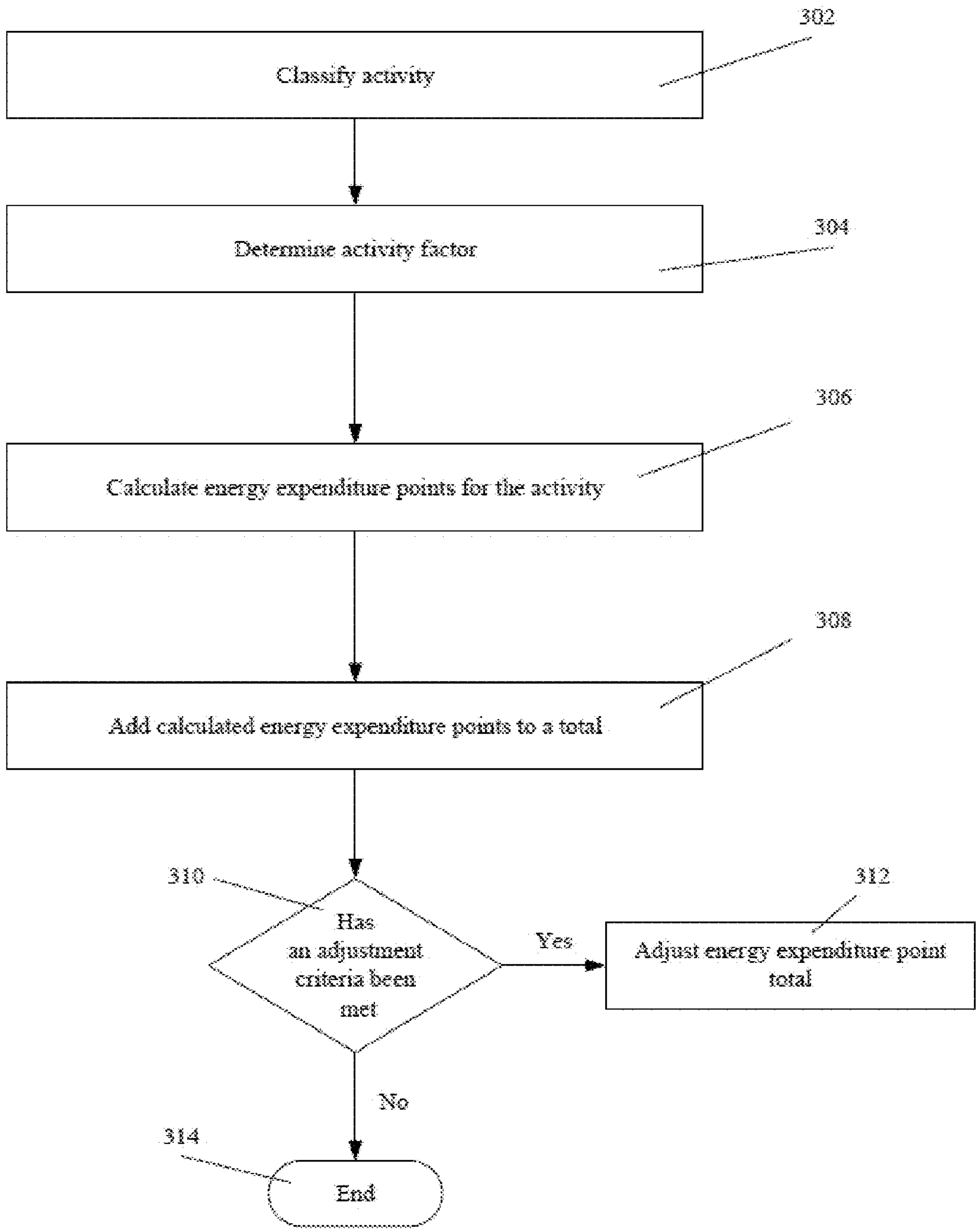

302
Classify activity
304
Determine activity factor
306
Calculate energy expenditure points for the activity
308
Add calculated energy expenditure points to a total
310
Has an adjustment criteria been met
Yes
312
Adjust energy expenditure point total
No
314
End

FIG. 4

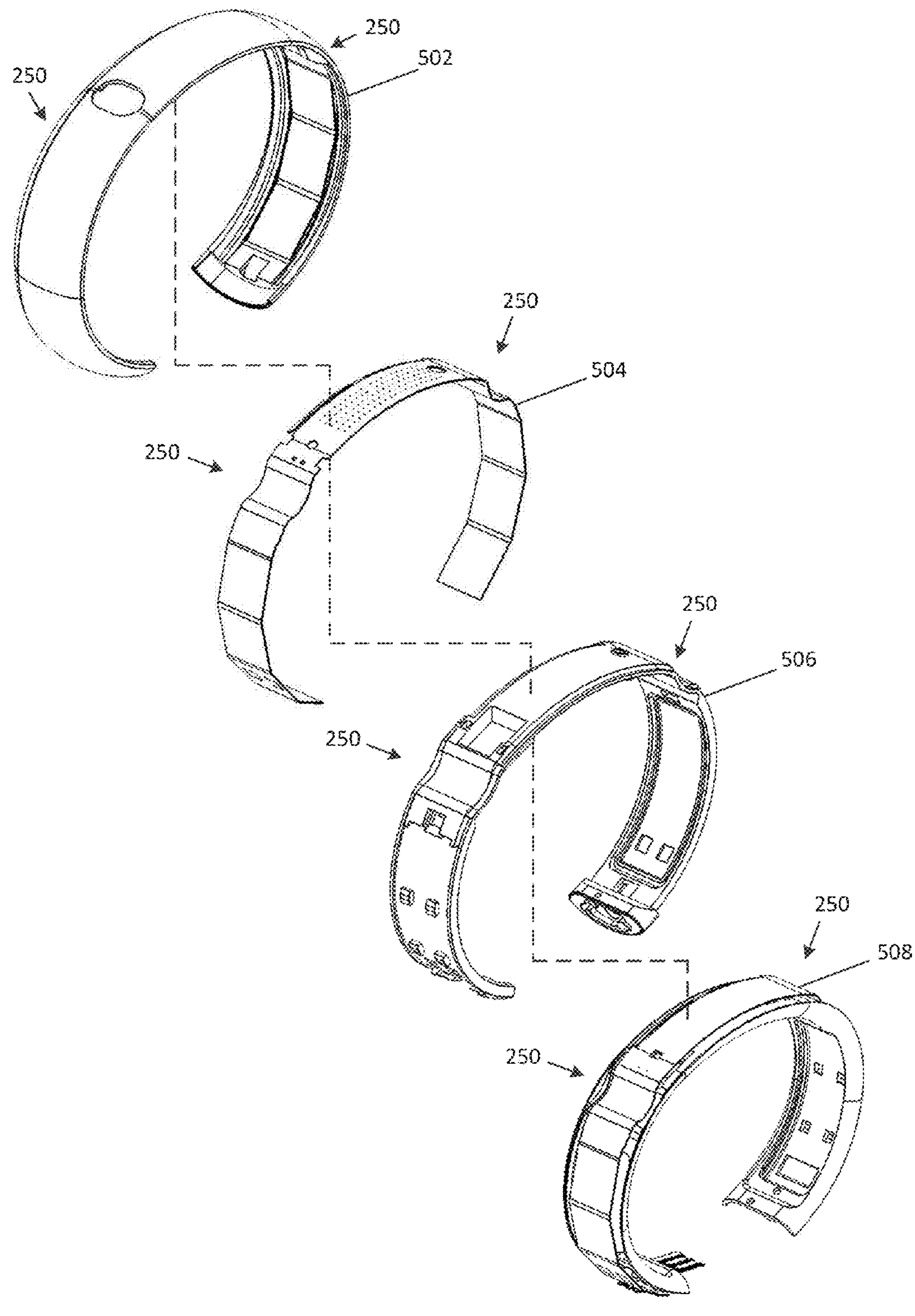


FIG. 5

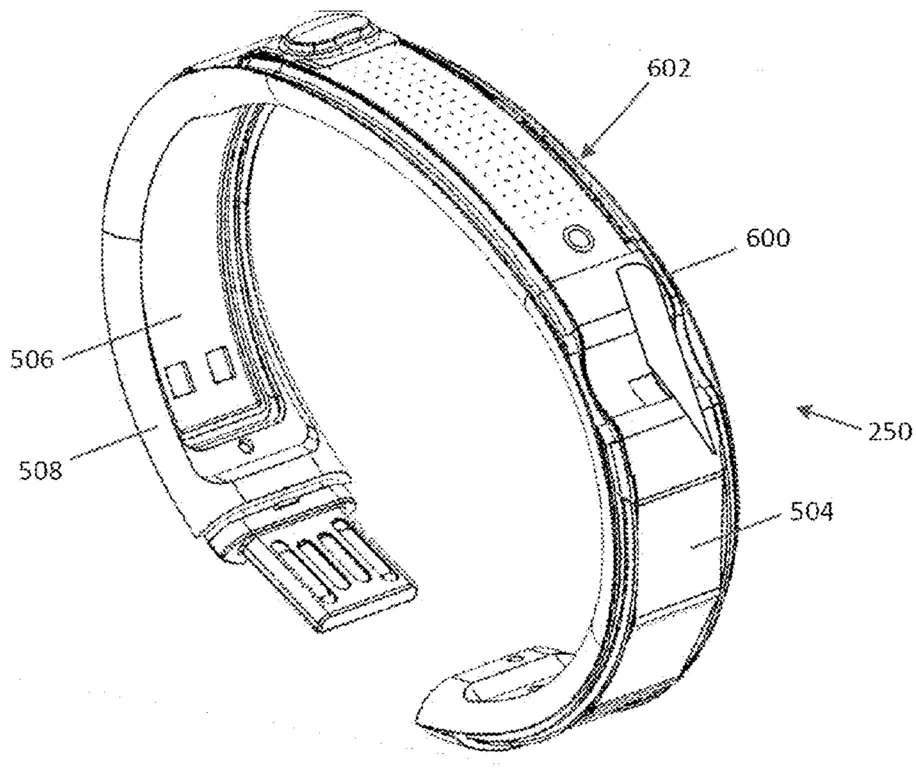

602
600
506
508
250
504

FIG. 6A

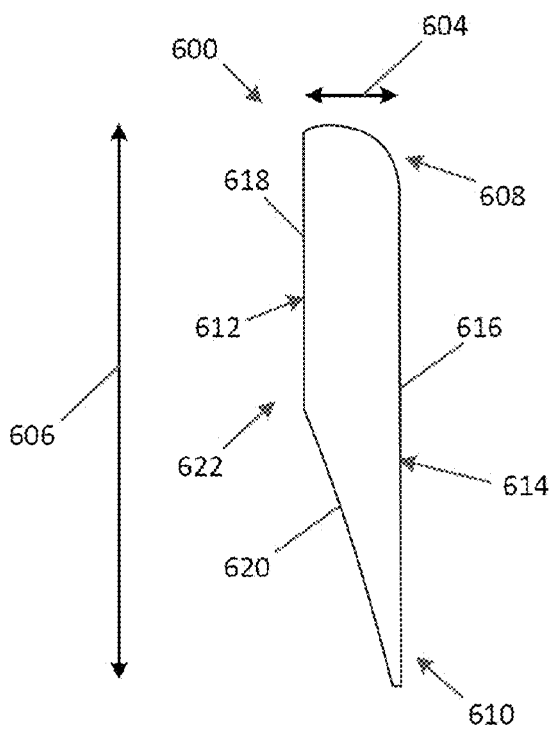

600
604
618
608
612
616
606
622
614
620
610

FIG. 6B

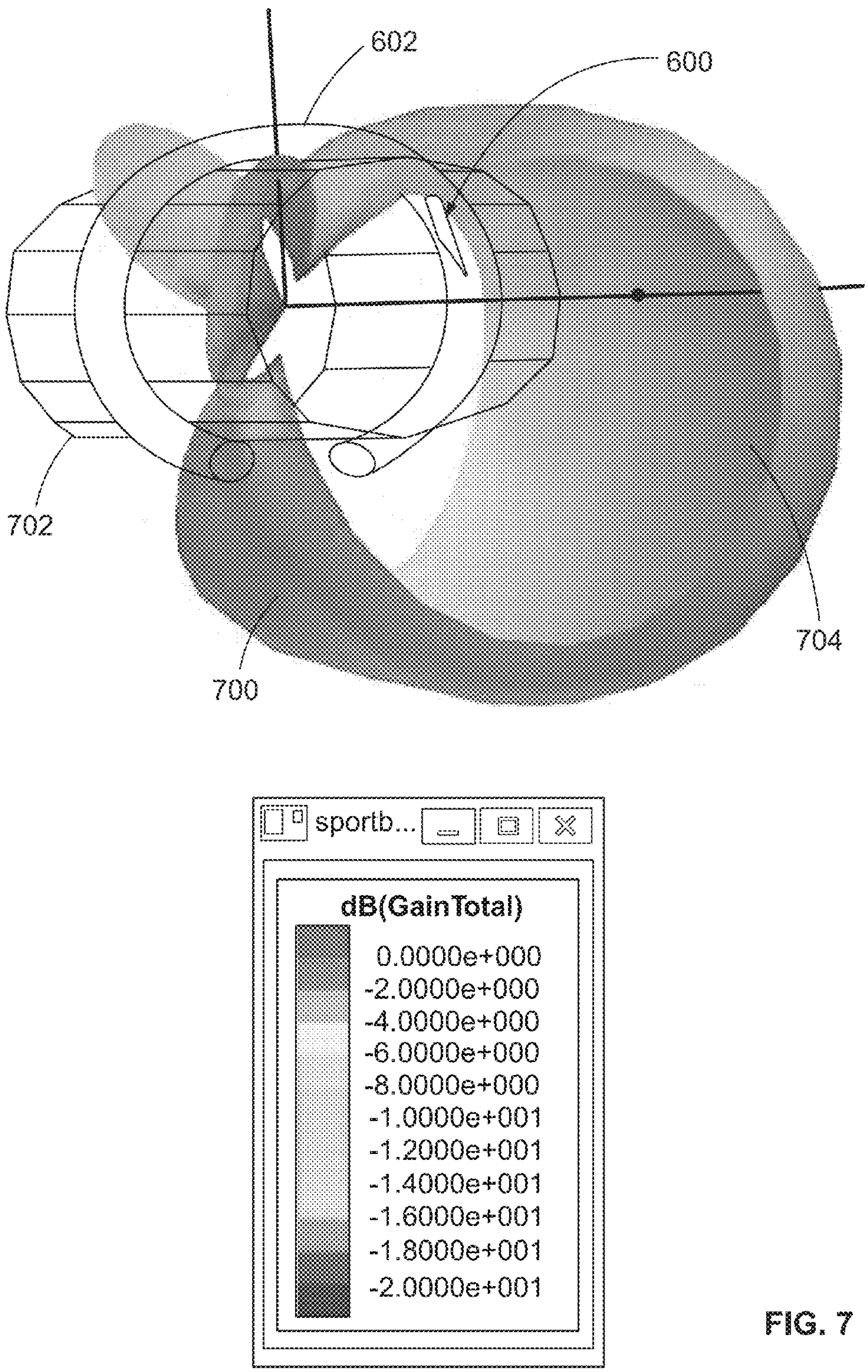

602
600
702
704
700
sportb...
dB(GainTotal)
0.0000e+000
-2.0000e+000
-4.0000e+000
-6.0000e+000
-8.0000e+000
-1.0000e+001
-1.2000e+001
-1.4000e+001
-1.6000e+001
-1.8000e+001
-2.0000e+001

FIG. 7

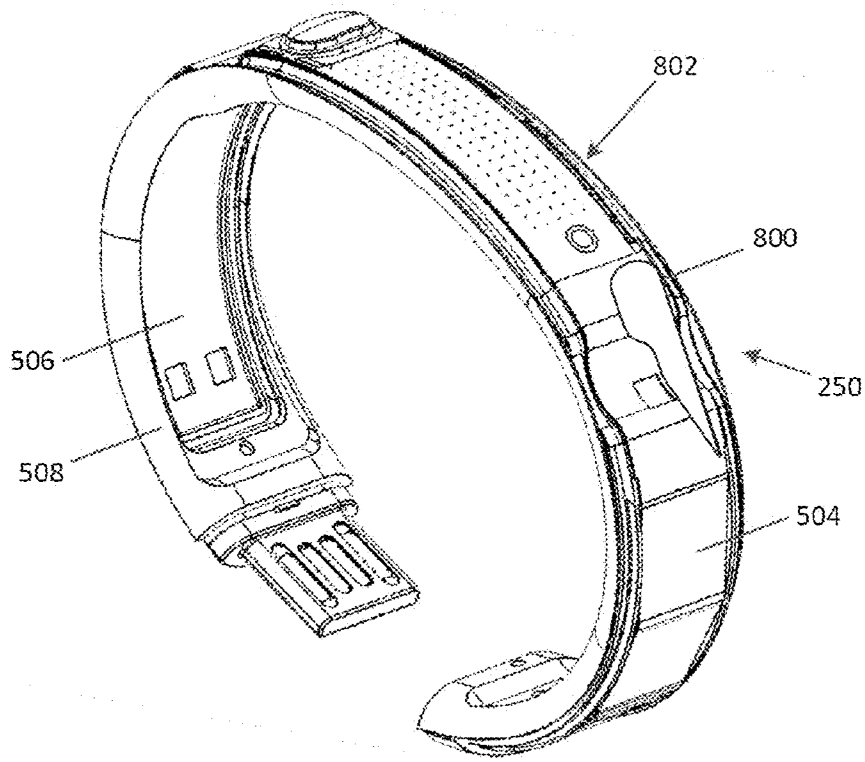

802
800
506
250
508
504

FIG. 8A

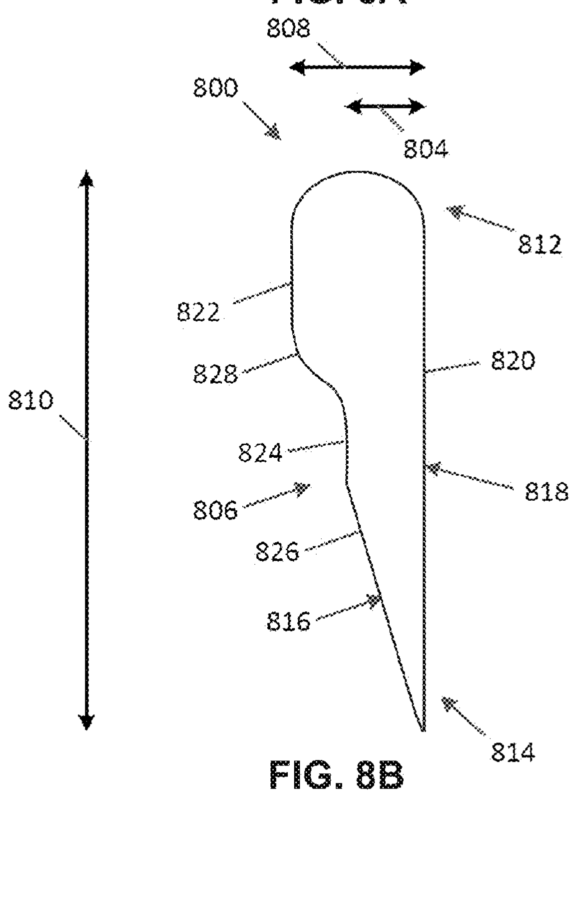

808
800
804
812
822
820
828
810
824
818
806
826
816
814

FIG. 8B

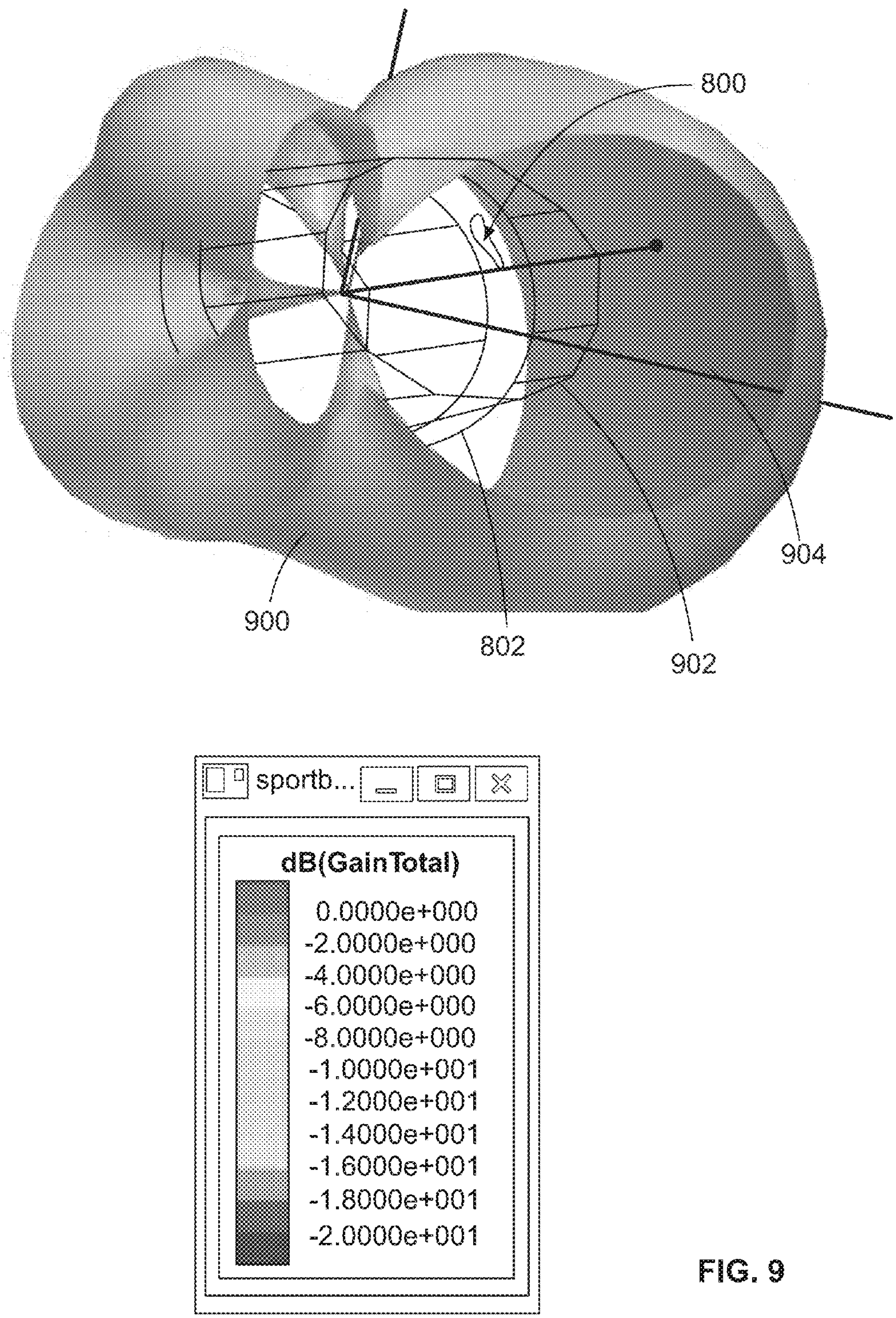

800
900
802
902
904
sportb...
dB(GainTotal)
0.0000e+000
-2.0000e+000
-4.0000e+000
-6.0000e+000
-8.0000e+000
-1.0000e+001
-1.2000e+001
-1.4000e+001
-1.6000e+001
-1.8000e+001
-2.0000e+001

FIG. 9

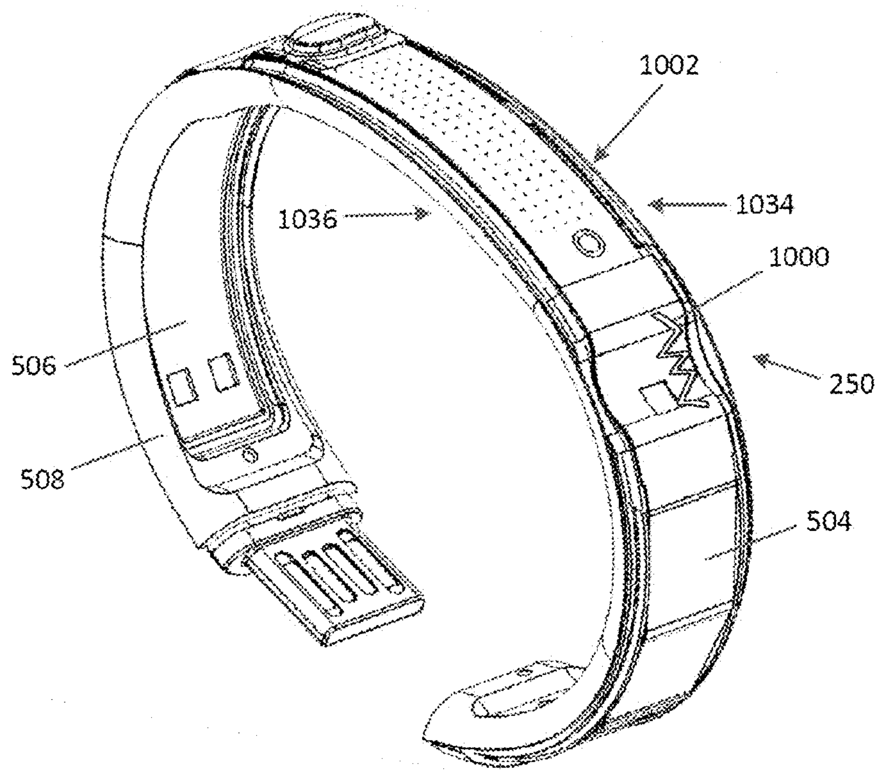


FIG. 10A

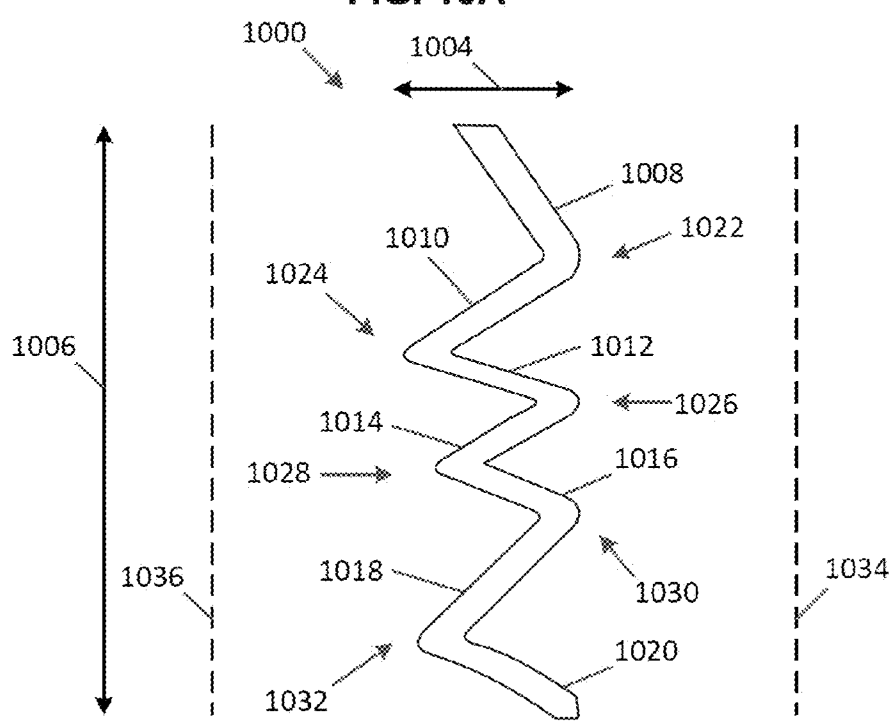


FIG. 10B

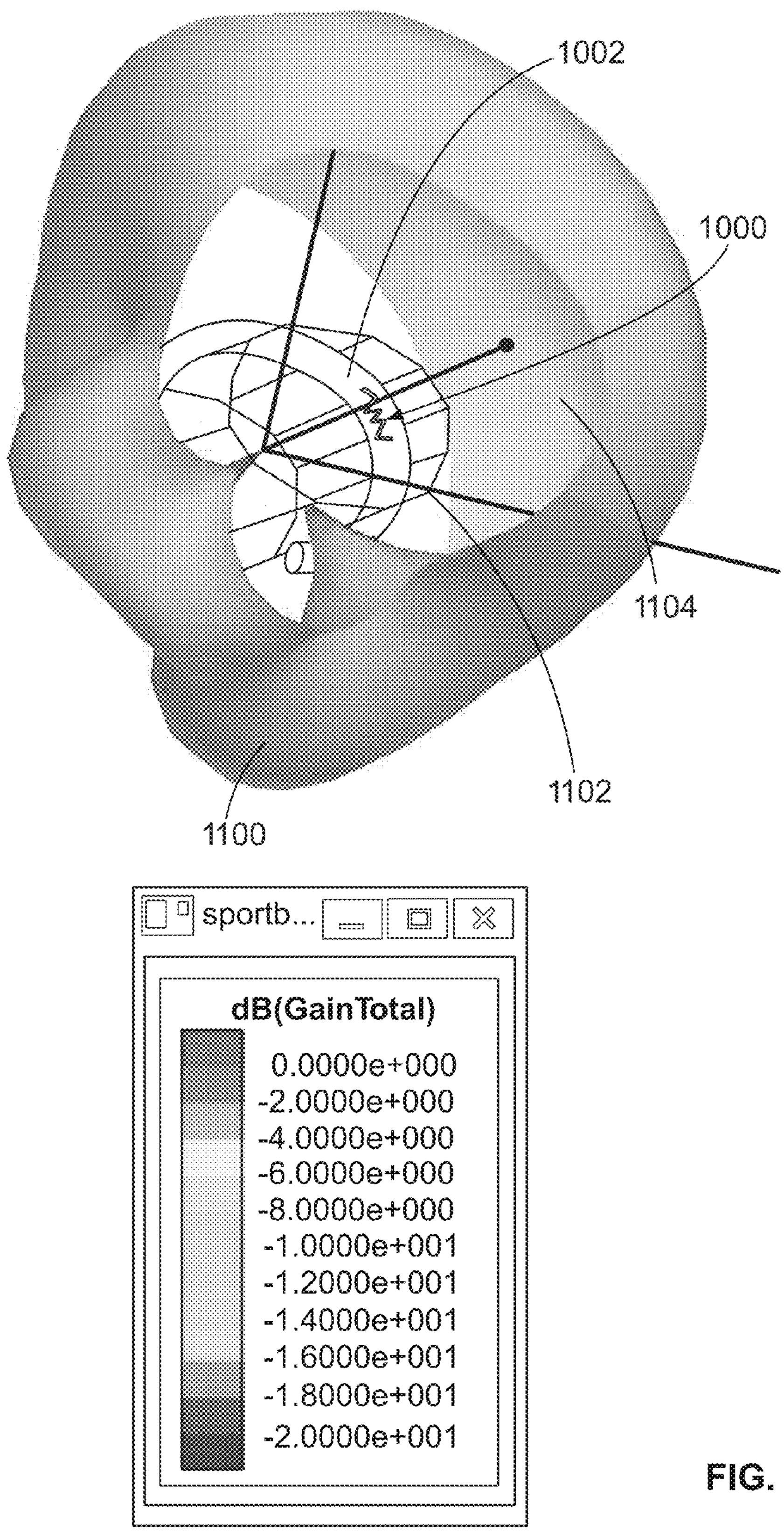

1002
1000
1104
1102
1100
α
sportb...
dB(GainTotal)
0.0000e+000
-2.0000e+000
-4.0000e+000
-6.0000e+000
-8.0000e+000
-1.0000e+001
-1.2000e+001
-1.4000e+001
-1.6000e+001
-1.8000e+001
-2.0000e+001

FIG. 11

WEARABLE DEVICE ASSEMBLY HAVING ANTENNA

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application Ser. No. 61/588,632 filed on Jan. 19, 2012 and titled, "Wearable Device Assembly Having Flexible Circuit Member," which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

Aspects of the invention generally relate to antennas of mobile devices and particularly relate to antennas for wrist-worn devices.

BACKGROUND

While most people appreciate the importance of physical fitness, many have difficulty finding the motivation required to maintain a regular exercise program. Some people find it particularly difficult to maintain an exercise regimen that involves continuously repetitive motions, such as running, walking and bicycling.

Additionally, individuals may view exercise as work or a chore and thus, separate it from enjoyable aspects of their daily lives. Often, this clear separation between athletic activity and other activities reduces the amount of motivation that an individual might have toward exercising. Further, athletic activity services and systems directed toward encouraging individuals to engage in athletic activities might also be too focused on one or more particular activities while an individual's interest are ignored. This may further decrease a user's interest in participating in athletic activities or using the athletic activity services and systems.

Therefore, improved systems and methods to address these and other shortcomings in the art are desired.

BRIEF SUMMARY

The following presents a simplified summary in order to provide a basic understanding of some aspects of the disclosure. The summary is not an extensive overview of the disclosure. It is neither intended to identify key or critical elements of the disclosure nor to delineate the scope of the disclosure. The following summary merely presents some concepts of the disclosure in a simplified form as a prelude to the description below.

A wrist-worn device that monitors movements of a user is provided. A sensor assembly of the wrist-worn device is configured to detect movement of the user and generate sensor data based on the movement detected. A controller connected to the sensor assembly obtains movement data based on the sensor data. An antenna connected to the controller is configured to operate at a desired frequency when a wrist of the user is received by the device such that the movement data is wirelessly transmittable from the wrist-worn device to an electronic device. The antenna may be tuned such that when the wrist of the user is received by the wrist-worn device, the antenna operates at a peak resonant frequency and when the wrist of the user is not received by the wrist-worn device, the antenna operates at an off-peak resonant frequency.

The antenna may be connected to and, in some cases, embedded in a flexible circuit member of the wrist-worn device, and the flexible circuit member may be wrapped around and connected to an internal spine member that extends through the body of the wrist worn device. A portion of the antenna may be located in a flex area defined by the body of the wrist-worn device.

The antenna may exhibit a different design and configuration depending on the size of the wrist-worn device. An antenna may have a first shape when installed in a wrist-worn device of a first size, may have a second shape when installed in a wrist-worn device of a second size larger than the first size, and may exhibit a third shape when installed in a wrist-worn device of a third size larger than both the first and second sizes.

An antenna for a wrist-worn device that monitors movements of a user is also provided in accordance with the principles set forth above.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is illustrated by way of example and not limited in the accompanying figures in which like reference numerals indicate similar elements and in which:

FIG. **1** is an example of an implementation of a system for providing personal training.

FIG. **2** is an example of an implementation of a computing device for providing personal training.

FIG. **3** is an example of an implementation of a wrist-worn sensor assembly device that monitors movements of a user.

FIG. **4** is a flowchart of example method steps for calculating energy expenditure.

FIG. **5** is an exploded view of portions of the wrist-worn sensor assembly device of FIG. **3**.

FIG. **6**A is an example of an implementation of a first type of antenna installed in a wrist-worn sensor assembly device.

FIG. **6**B is a close-up view of the first type of antenna of FIG. **6**A

FIG. **7** is an example of a radiation pattern generated by the first type of antenna of FIG. **6** when the wrist-worn sensor assembly device is worn around the wrist of a user.

FIG. **8**A is an example of an implementation of a second type of antenna installed in a wrist-worn sensor assembly device.

FIG. **8**B is a close-up view of the second type of antenna of FIG. **8**A.

FIG. **9** is an example of a radiation pattern generated by the second type of antenna of FIG. **8** when the wrist-worn sensor assembly device is worn around the wrist of a user.

FIG. **10**A is an example of an implementation of a third type of antenna installed in a wrist-worn sensor assembly device.

FIG. **10**B is a close-up view of the third type of antenna of FIG. **10**A.

FIG. **11** is an example of a radiation pattern generated by the third type of antenna of FIG. **10** when the wrist-worn sensor assembly device is worn around the wrist of a user.

DETAILED DESCRIPTION

In the following description of the various embodiments, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration various embodiments in which the disclosure may be practiced. It is to be understood that other embodiments may be utilized and structural and functional modifications may be made without departing from the scope and spirit of the present disclosure. Further, headings within this disclosure should not be considered as limiting aspects of the disclosure.

Those skilled in the art with the benefit of this disclosure will appreciate that the example embodiments are not limited to the example headings.

1. Example Personal Training System

1.1. Illustrative Computing Devices

FIG. **1** illustrates an example of a personal training system **100** in accordance with example embodiments. Example system **100** may include one or more electronic devices, such as computer **102**. Computer **102** may comprise a mobile terminal, such as a telephone, music player, tablet, netbook or any portable device. In other embodiments, computer **102** may comprise a set-top box (STB), desktop computer, digital video recorder(s) (DVR), computer server(s), and/or any other desired computing device. In certain configurations, computer **102** may comprise a gaming console, such as for example, a Microsoft® XBOX, Sony® PlayStation, and/or a Nintendo® Wii gaming consoles. Those skilled in the art will appreciate that these are merely example consoles for descriptive purposes and this disclosure is not limited to any console or device.

Turning briefly to FIG. **2**, computer **102** may include computing unit **104**, which may comprise at least one processing unit **106**. Processing unit **106** may be any type of processing device for executing software instructions, such as for example, a microprocessor device. Computer **102** may include a variety of non-transitory computer readable media, such as memory **108**. Memory **108** may include, but is not limited to, random access memory (RAM) such as RAM **110**, and/or read only memory (ROM), such as ROM **112**. Memory **108** may include any of: electronically erasable programmable read only memory (EEPROM), flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic storage devices, or any other medium that can be used to store the desired information and that can be accessed by computer **102**.

The processing unit **106** and the system memory **108** may be connected, either directly or indirectly, through a bus **114** or alternate communication structure to one or more peripheral devices. For example, the processing unit **106** or the system memory **108** may be directly or indirectly connected to additional memory storage, such as a hard disk drive **116**, a removable magnetic disk drive, an optical disk drive **118**, and a flash memory card. The processing unit **106** and the system memory **108** also may be directly or indirectly connected to one or more input devices **120** and one or more output devices **122**. The output devices **122** may include, for example, a display device **136**, television, printer, stereo, or speakers. In some embodiments one or more display devices may be incorporated into eyewear. The display devices incorporated into eyewear may provide feedback to users. Eyewear incorporating one or more display devices also provides for a portable display system. The input devices **120** may include, for example, a keyboard, touch screen, a remote control pad, a pointing device (such as a mouse, touchpad, stylus, trackball, or joystick), a scanner, a camera or a microphone. In this regard, input devices **120** may comprise one or more sensors configured to sense, detect, and/or measure athletic movement from a user, such as user **124**, shown in FIG. **1**.

Looking again to FIG. **1**, image-capturing device **126** and/or sensor **128** may be utilized in detecting and/or measuring athletic movements of user **124**. In one embodiment, data obtained from image-capturing device **126** or sensor **128** may directly detect athletic movements, such that the data obtained from image-capturing device **126** or sensor **128** is directly correlated to a motion parameter. Yet, in other embodiments, data from image-capturing device **126** and/or sensor **128** may be utilized in combination, either with each other or with other sensors to detect and/or measure movements. Thus, certain measurements may be determined from combining data obtained from two or more devices. Image-capturing device **126** and/or sensor **128** may include or be operatively connected to one or more sensors, including but not limited to: an accelerometer, a gyroscope, a location-determining device (e.g., GPS), light sensor, temperature sensor (including ambient temperature and/or body temperature), heart rate monitor, image-capturing sensor, moisture sensor and/or combinations thereof. Example uses of illustrative sensors **126**, **128** are provided below in Section I.C, entitled "Illustrative Sensors." Computer **102** may also use touch screens or image capturing device to determine where a user is pointing to make selections from a graphical user interface. One or more embodiments may utilize one or more wired and/or wireless technologies, alone or in combination, wherein examples of wireless technologies include Bluetooth® technologies, Bluetooth® low energy technologies, and/or ANT technologies.

1.2. Illustrative Network

Computer **102**, computing unit **104**, and/or any other electronic devices may be directly or indirectly connected to one or more network interfaces, such as example interface **130** (shown in FIG. **2**) for communicating with a network, such as network **132**. In the example of FIG. **2**, network interface **130**, may comprise a network adapter or network interface card (NIC) configured to translate data and control signals from the computing unit **104** into network messages according to one or more communication protocols, such as the Transmission Control Protocol (TCP), the Internet Protocol (IP), and the User Datagram Protocol (UDP). These protocols are well known in the art, and thus will not be discussed here in more detail. An interface **130** may employ any suitable connection agent for connecting to a network, including, for example, a wireless transceiver, a power line adapter, a modem, or an Ethernet connection. Network **132**, however, may be any one or more information distribution network(s), of any type(s) or topology(s), alone or in combination(s), such as internet(s), intranet(s), cloud(s), LAN(s). Network **132** may be any one or more of cable, fiber, satellite, telephone, cellular, wireless, etc. Networks are well known in the art, and thus will not be discussed here in more detail. Network **132** may be variously configured such as having one or more wired or wireless communication channels to connect one or more locations (e.g., schools, businesses, homes, consumer dwellings, network resources, etc.), to one or more remote servers **134**, or to other computers, such as similar or identical to computer **102**. Indeed, system **100** may include more than one instance of each component (e.g., more than one computer **102**, more than one display **136**, etc.).

Regardless of whether computer **102** or other electronic device within network **132** is portable or at a fixed location, it should be appreciated that, in addition to the input, output and storage peripheral devices specifically listed above, the computing device may be connected, such as either directly, or through network **132** to a variety of other peripheral devices, including some that may perform input, output and storage functions, or some combination thereof. In certain embodiments, a single device may integrate one or more components shown in FIG. **1**. For example, a single device may include computer **102**, image-capturing device **126**, sensor **128**, display **136** and/or additional components. In one embodiment, sensor device **138** may comprise a mobile terminal having a display **136**, image-capturing device **126**, and one or more sensors **128**. Yet, in another embodiment, image-capturing device **126**, and/or sensor **128** may be peripherals configured to be operatively connected to a media device, including for example, a gaming or media system. Thus, it goes from the foregoing that this disclosure is not limited to stationary systems and methods. Rather, certain embodiments may be carried out by a user **124** in almost any location.

1.3. Illustrative Sensors

Computer **102** and/or other devices may comprise one or more sensors **126**, **128** configured to detect and/or monitor at least one fitness parameter of a user **124**. Sensors **126** and/or **128** may include, but are not limited to: an accelerometer, a gyroscope, a location-determining device (e.g., GPS), light sensor, temperature sensor (including ambient temperature and/or body temperature), sleep pattern sensors, heart rate monitor, image-capturing sensor, moisture sensor and/or combinations thereof. Network **132** and/or computer **102** may be in communication with one or more electronic devices of system **100**, including for example, display **136**, an image capturing device **126** (e.g., one or more video cameras), and sensor **128**, which may be an infrared (IR) device. In one embodiment sensor **128** may comprise an IR transceiver. For example, sensors **126**, and/or **128** may transmit waveforms into the environment, including towards the direction of user **124** and receive a "reflection" or otherwise detect alterations of those released waveforms. In yet another embodiment, image-capturing device **126** and/or sensor **128** may be configured to transmit and/or receive other wireless signals, such as radar, sonar, and/or audible information. Those skilled in the art will readily appreciate that signals corresponding to a multitude of different data spectrums may be utilized in accordance with various embodiments. In this regard, sensors **126** and/or **128** may detect waveforms emitted from external sources (e.g., not system **100**). For example, sensors **126** and/or **128** may detect heat being emitted from user **124** and/or the surrounding environment. Thus, image-capturing device **126** and/or sensor **128** may comprise one or more thermal imaging devices. In one embodiment, image-capturing device **126** and/or sensor **128** may comprise an IR device configured to perform range phenomenology. As a non-limited example, image-capturing devices configured to perform range phenomenology are commercially available from Flir Systems, Inc. of Portland, Ore. Although image capturing device **126** and sensor **128** and display **136** are shown in direct (wirelessly or wired) communication with computer **102**, those skilled in the art will appreciate that any may directly communicate (wirelessly or wired) with network **132**.

1.3.1 Multi-Purpose Electronic Devices

User **124** may possess, carry, and/or wear any number of electronic devices, including sensory devices **138**, **140**, **142**, and/or **144**. In certain embodiments, one or more devices **138**, **140**, **142**, **144** may not be specially manufactured for fitness or athletic purposes. Indeed, aspects of this disclosure relate to utilizing data from a plurality of devices, some of which are not fitness devices, to collect, detect, and/or measure athletic data. In one embodiment, device **138** may comprise a portable electronic device, such as a telephone or digital music player, including an IPOD®, IPAD®, or iPhone®, brand devices available from Apple, Inc. of Cupertino, Calif. or Zune® or Microsoft® Windows devices available from Microsoft of Redmond, Wash. As known in the art, digital media players can serve as both an output device for a computer (e.g., outputting music from a sound file or pictures from an image file) and a storage device. In one embodiment, device **138** may be computer **102**, yet in other embodiments, computer **102** may be entirely distinct from device **138**. Regardless of whether device **138** is configured to provide certain output, it may serve as an input device for receiving sensory information. Devices **138**, **140**, **142**, and/or **144** may include one or more sensors, including but not limited to: an accelerometer, a gyroscope, a location-determining device (e.g., GPS), light sensor, temperature sensor (including ambient temperature and/or body temperature), heart rate monitor, image-capturing sensor, moisture sensor and/or combinations thereof. In certain embodiments, sensors may be passive, such as reflective materials that may be detected by image-capturing device **126** and/or sensor **128** (among others). In certain embodiments, sensors **144** may be integrated into apparel, such as athletic clothing. For instance, the user **124** may wear one or more on-body sensors **144***a-b*. Sensors **144** may be incorporated into the clothing of user **124** and/or placed at any desired location of the body of user **124**. Sensors **144** may communicate (e.g., wirelessly) with computer **102**, sensors **128**, **138**, **140**, and **142**, and/or camera **126**. Examples of interactive gaming apparel are described in U.S. patent application Ser. No. 10/286,396, filed Oct. 30, 2002, and published as U.S. Pat. Pub. No. 2004/0087366, the contents of which are incorporated herein by reference in its entirety for any and all non-limiting purposes. In certain embodiments, passive sensing surfaces may reflect waveforms, such as infrared light, emitted by image-capturing device **126** and/or sensor **128**. In one embodiment, passive sensors located on user's **124** apparel may comprise generally spherical structures made of glass or other transparent or translucent surfaces which may reflect waveforms. Different classes of apparel may be utilized in which a given class of apparel has specific sensors configured to be located proximate to a specific portion of the user's **124** body when properly worn. For example, golf apparel may include one or more sensors positioned on the apparel in a first configuration and yet soccer apparel may include one or more sensors positioned on apparel in a second configuration.

Devices **138**-**144** may communicate with each other, either directly or through a network, such as network **132**. Communication between one or more of devices **138**-**144** may take place via computer **102**. For example, two or more of devices **138**-**144** may be peripherals operatively connected to bus **114** of computer **102**. In yet another embodiment, a first device, such as device **138** may communicate with a first computer, such as computer **102** as well as another device, such as device **142**, however, device **142** may not be configured to connect to computer **102** but may communicate with device **138**. Those skilled in the art will appreciate that other configurations are possible.

Some implementations of the example embodiments may alternately or additionally employ computing devices that are intended to be capable of a wide variety of functions, such as a desktop or laptop personal computer. These computing devices may have any combination of peripheral devices or additional components as desired. Also, the components shown in FIG. **2** may be included in the server **134**, other computers, apparatuses, etc.

1.3.2. Illustrative Apparel/Accessory Sensors

In certain embodiments, sensory devices **138**, **140**, **142** and/or **144** may be formed within or otherwise associated with user's **124** clothing or accessories, including a watch, armband, wristband, necklace, shirt, shoe, or the like. Examples of shoe-mounted and wrist-worn devices (devices **140** and **142**, respectively) are described immediately below, however, these are merely example embodiments and this disclosure should not be limited to such.

As shown in FIG. **3**, an example of an implementation of a wrist-worn sensory assembly device **226** is shown ("wrist-worn device" or "device"). The device **226** (which may resemble or be sensory device **142** shown in FIG. **1**) may be configured to be worn by user **124**, such as around a wrist, arm, ankle or the like. Device **226** may monitor athletic movements of a user, including all-day activity of user **124**. In this regard, device assembly **226** may detect athletic movement during user's **124** interactions with computer **102** and/or operate independently of computer **102**. For example, in one embodiment, device **226** may be an-all day activity monitor that measures activity regardless of the user's proximity or interactions with computer **102**. Device **226** may communicate directly with network **132** and/or other devices, such as devices **138** and/or **140**. In other embodiments, athletic data obtained from device **226** may be utilized in determinations conducted by computer **102**, such as determinations relating to which exercise programs are presented to user **124**. In one embodiment, device **226** may also wirelessly interact with a mobile device, such as device **138** associated with user **124** or a remote website such as a site dedicated to fitness or health related subject matter. At some predetermined time, the user may wish to transfer data from the device **226** to another location.

As shown in FIG. **3**, device **226** may include an input mechanism, such as a depressible input button **228** assist in operation of the device **226**. The input button **228** may be operably connected to a controller **230** and/or any other electronic components, such as one or more of the elements discussed in relation to computer **102** shown in FIG. **2**. Controller **230** may be embedded or otherwise part of housing **232**. Housing **232** may be formed of one or more materials, including elastomeric components and comprise one or more displays, such as display **234**. The display may be considered an illuminable portion of the device **226**. The display **234** may include a series of individual lighting elements or light members such as LED lights **234** in an exemplary embodiment. The LED lights may be formed in an array and operably connected to the controller **230**. Device **226** may include an indicator system **236**, which may also be considered a portion or component of the overall display **234**. It is understood that the indicator system **236** can operate and illuminate in conjunction with the display **234** (which may have pixel member **235**) or completely separate from the display **234**. The indicator system **236** may also include a plurality of additional lighting elements or light members **238**, which may also take the form of LED lights in an exemplary embodiment. In certain embodiments, indicator system may provide a visual indication of goals, such as by illuminating a portion of lighting members **238** to represent accomplishment towards one or more goals.

A fastening mechanism **240** can be unlatched wherein the device **226** can be positioned around a wrist of the user **124** and the fastening mechanism **240** can be subsequently placed in a latched position. The user can wear the device **226** at all times if desired. In one embodiment, fastening mechanism **240** may comprise an interface, including but not limited to a USB port, for operative interaction with computer **102** and/or devices **138**, **140**.

It will be understood that the device **226** will undergo some flexing as the device is positioned around the wrist of a user **124** or removed from the wrist of the user **124**. When the fastening mechanism **240** is unlatched and the device **226** pulled open, the device will flex at various flex areas **250** to allow the wrist to be received by the device as the device wraps around the wrist of the user **124**. The device **226** flexes in a similar fashion when the fastening mechanism **240** is unlatched and the device pulled open to remove the device from the wrist of the user **124**. In the example device **226** of FIG. **3**, the device includes two flex areas **250** located near what may be described as the "shoulders" of the device.

In certain embodiments, device **226** may comprise a sensor assembly (not shown in FIG. **3**). The sensor assembly may comprise a plurality of different sensors. In an example embodiment, the sensor assembly may comprise or permit operative connection to an accelerometer (including in the form of a multi-axis accelerometer), heart rate sensor, location-determining sensor, such as a GPS sensor, and/or other sensors. Detected movements or parameters from device's **142** sensor(s), may include (or be used to form) a variety of different parameters, metrics or physiological characteristics including but not limited to speed, distance, steps taken, and energy expenditure such as calories, heart rate, sweat detection, effort, oxygen consumed, and/or oxygen kinetics. Such parameters may also be expressed in terms of activity points or currency earned by the user based on the activity of the user.

2. Energy Expenditure Point Calculations

FIG. **4** is a flowchart of example method steps for calculating energy expenditure values, such as points, in accordance with an embodiment of the invention. Certain embodiments may classify physical motions of a user. For example, at illustrative step **302**, one or more activities may be classified. System **100** may process data received from one or more of the sensors described above to attempt to classify a user's activity. For example, system **100** may compare a sensor signal to one or more signal or activity "templates" or "signatures" corresponding to selected activities. In certain embodiments, templates may be created by attaching sensors to a user and monitoring signals generated when the user performs various activities. In accordance with certain embodiments, an activity may be associated with an activity template specific to user **124**. In one such embodiment, user **124** may be assigned a default template for a specific activity unless a specific template has been assigned to that activity. Thus, user **124** may create or receive (but is not required to create or receive) an activity template that may be more accurate than a default template because the template is more specific to the user and/or the activity. User **124** may have the option to create templates for one or more predefined or undefined activities. A specific or otherwise new template might be shared among the community of users. Shared templates may be based on a variety of different sensors. In some embodiments templates may be refined or adjusted for use with different sensors. For example, a template that was created for use with a shoe based sensor may be refined for use with a wrist worn sensor.

An activity template may be created from data obtained from one or more of a plurality of different sensors. For example, a first group of sensors (e.g. sensors **126** and **138**) may be utilized in the formation or refinement of a first activity template; however, a second group of sensors (e.g., sensors **128** and **140**) may be utilized in the formation or refinement of a second activity template. In yet further embodiments, a third group of sensors, such as sensors **128** and **140** (and/or other sensors), may be utilized in the creation of the first activity template for a second user (e.g., not user **124**) than utilized for the formation of the same activity template as user **124**. Thus, in accordance with certain embodiments, there is no requirement that data from a specific sensor be received for either: 1) the same activity template for different users; and/or 2) different activity templates for the same user.

In one embodiment, a wrist mounted accelerometer, which may be a multi-axis accelerometer, may be attached to a user and signal templates based on the accelerometer output when the user runs, walks, etc. may be created. The templates may be functions of the sensor(s) used and/or the locations of the sensor(s). In some embodiments, a single signal (or value) is created by combining multiple signals (or values). For example, three outputs of a three axis accelerometer may be summed or otherwise combined to create one or more signals. Example step **302** may include comparing a signal, multiple signals or a combination of signals to one or more templates. In some embodiments, a best match approach may be implemented in which every activity is attempted to be classified. In other embodiments, if a signal, multiple signals or combination of signals does not sufficiently match a template, the activity may remain unclassified.

After at least one of user's **124** activity is classified, step **304** may be implemented to determine a corresponding activity factor. An activity factor may correspond to brisk running, running at a moderate pace, walking slowly or any other activity. An activity factor for an activity may be related to calories or energy generally required to perform the activity. If an activity was not classified in step **302**, a default activity factor may be selected or derived. In some embodiments multiple default activity factors may be utilized. An activity's intensity, duration or other characteristic(s) may be assessed, from which one or more default activity factors may be applied. The plural activity factors may be set via medians/averages, ranges, or other statistical approaches.

In various embodiments of the invention, activity factors are used to calculate energy expenditure points. After at least one of user's **124** activity is classified, in step **306** energy expenditure points may be calculated. The use of energy expenditure points allows for comparison of activity levels and may promote collaboration among users, normalize for competition among users of different capabilities, and otherwise encourage activity.

In one embodiment, energy expenditure points are calculated as follows:

$$\text{EEPs}=\text{AF}*D \tag{1}$$

wherein EEPs refer to energy expenditure points; AF refers to the activity factor determined in step **304**; and D refers to the duration of the activity classified in step **302**.

Step **306** may be performed at a device that includes sensors that monitor activity and/or at another device that includes a processor, such as a mobile phone (see, e.g., **138**) or server (see, e.g., **134**).

In some embodiments equation 1 may be modified to include a scalar that is multiplied by the activity factor and duration. The scalar may be selected so that typical energy expenditure points fall within a desired range. The range of points may be desired for various games or competitions.

Variations of equation 1 may be used in other embodiments of the invention. In some embodiments, users may select an equation and/or one or more variables, such as for example, a scalar. Equations may be selected for different games and competitions. In one example a group may set handicaps among the players based on fitness, so that the most fit generate EEPs only if they do a common activity or set of activities for longer period(s) of time. A group of users participating in an energy expenditure point competition may agree on a particular equation or method before beginning the competition. In some embodiments of the invention, a user may participate in multiple competitions and earn different points for the same activity because of different calculation methods. For example, a user may be participating in two competitions that have unique calculation methods. The user may earn two different point totals for the two different games and a third point total foe their overall energy expenditure. Some point totals may be maintained separate from an overall point total.

After the energy expenditure points are calculated, the calculated points may be combined, such as being added, to a total in step **308**. The total may allow user **124** (and/or selected individuals or groups approved by user **124**) to see how many points are earned over various periods of time, such as days, weeks and months. Totals may also be calculated for multiple time periods. For example, a user may receive totals for periods that include **24** hours, one week, one month and one year. In some embodiments users may select other time periods or deselect time periods. A user may track multiple time periods concurrently and track points award since the beginning of use of a device or start of a program. The total for any giving time period may represent points earned for several activities. For example, in a day a user may receive points for walking, jogging and sprinting during different time periods. As mentioned above, the points earned for each activity may be a function of a corresponding activity factor.

Energy expenditure points may be deducted when user **124** has been inactive for a predetermined period of time or enhanced when certain criteria are met. This feature may be included with all calculations or may be used in various games and competitions. For example, in step **314** it may be determined whether an adjustment criteria has been met. The adjustment criteria may include inactivity for a predetermined time period. In some embodiments inactivity is not determined by merely determining that an amount of time has passed since with user was active.

When an adjustment criteria has been met, the total of energy expenditure points may be adjusted in step **310**. The adjustment may be a function of duration of inactivity. In some embodiments, a device may warn user **124** (or authorized groups/individuals) that they are close to receiving a reduction in energy expenditure points to encourage activity. It yet other embodiments, an alarm may notify user **124** (and/or other authorized individuals and/or groups) that they have received a reduction of energy expenditure points. In certain embodiments, team-mates and/or competing users may be notified of a reduction (or potential for reduction). In further embodiments, teachers, trainers, and/or parents may more readily monitor the physical activity of others. When a user has not been inactive, the process may end in step **314**. Of course, the method shown in FIG. **3** may be repeated at various intervals and allow for tracking points concurrently for different time periods, such as days, weeks and years.

In another aspect, a device **10**, such as device **226** may provide a message based on inactivity or non-active periods. If the device senses that the user has been in a non-active (e.g., low activity) state for a predetermined amount of time, an alert message may be delivered to the indicator system or display to remind the user to become more active. The alert message can be delivered in any of the manners described herein. The threshold levels of a low activity state and amount of inactive time could also vary and be individually set by the user.

In some arrangements, user non-activity or inactivity may also be detected and affect the user's progress toward completion of an activity goal. For example, inactivity may be detected when a user does not exhibit movement of a particular level or a type of movement for a specified amount of time, does not exhibit a heart rate of at least a threshold level, does not move a sufficient amount of distance over an amount of time and the like and/or combinations thereof. For arrangements in which a user accumulates activity points to reach an activity point goal, points or a value may be deducted from the user's activity point or other activity metric total when an amount of non-activity (e.g., inactivity or sedentary state) is detected. Various conversion rates for converting inactivity to activity point deductions may be used. In a particular example, 10 minutes of inactivity may correspond to a 5 point deduction. In another example, 30 minutes of inactivity may correspond to a 100 point deduction. Loss or deduction of activity points may be linear or may be non-linear, for example, exponential, parabolic and the like.

A user's non-active time may include inactive time and sedentary time. Inactivity and sedentary time may be defined by different movement, heart-rate, step or other thresholds or may be defined using the same thresholds. In one example, sedentary time may have a higher threshold (e.g., requiring a higher level of activity) than an inactivity threshold. That is, an individual may be considered sedentary but not inactive. The non-active threshold may correspond to the sedentary threshold or a higher threshold, if desired. Alternatively, an inactivity threshold may be greater than a sedentary threshold. There may also be multiple sedentary thresholds, inactivity thresholds and/or non-active thresholds (e.g., each of the sedentary and inactivity thresholds may be a non-active threshold). Different point deductions or rates of point deductions may also be defined between the multiple thresholds and levels of little to no activity (e.g., non-activity). For example, a user may lose 50 points per hour for inactivity and 30 points per hour for sedentary activity or vice versa. Further, activity point deduction may be triggered at different times depending on if the user is inactive or sedentary. For instance, a user may begin losing activity points after 30 minutes of inactivity or 45 minutes of being sedentary. Additional thresholds (e.g., more than two thresholds) and corresponding rates of activity point loss may also be defined.

In some arrangements, various sensors may be used to detect non-active periods of time. As discussed, non-activity time periods may be defined based on heart-rate, amplitude of a movement signal, step rate (e.g., <10 steps per minute), or the like. Alternatively or additionally, inactivity and sedentary time periods may be measured based on a physical position, body position, body orientation, body posture of or type of activity being performed by the individual. The detrimental effects of various physical inactivity or sedentary body positions or orientations may also differ. Accordingly, 30 minutes of reclining may introduce the same health risks as 45 minutes of sitting. The potential for health risks may also be time-dependent. Accordingly, non-activity (e.g., sleeping) for a specified range of durations and during a specified range of time might not introduce health risks. In one example, sleeping for 7-9 hours between 9 PM and 9 AM might not introduce detrimental health risks and thus, might not contribute to activity point or other activity metric value deduction. Indeed, in some example, a lack of inactivity (such as sleep) for a specified range of durations and/or during a specified range of time may be considered detrimental to a user's health. Thus, activity points may be deducted or activity points may be accumulated at a slower rate during these times.

Alternatively or additionally, the amount by which a value of the activity metric (e.g., an activity points) is decreased may be determined based on time of day, location of the user, physical position of the user, level of inactivity and the like. For example, a user may lose greater value in an activity metric and/or at a faster rate during the afternoon than during the evenings. In another example, if a user is at a gym, the user may lose fewer activity points or other activity metric or lose value in the metric at a slower rate than if the user was located at home.

To account for the variances in types of non-active activity (e.g., below a requisite level of movement to be considered activity), a system may distinguish between physical body positions or orientations including, for example, sleeping, reclining, sitting and standing. Distinguishing between different physical body positions and orientations may include placing sensors at different locations of the user's body to detect the individual positions of each body part. The physical body position of the user may then be determined based on the relative positions of the body parts to one another. For example, when a knee location sensor is within a first threshold distance of a waist or chest sensor, the system may determine that the user is sitting. If the knee location sensor is outside of the first threshold distance, the system may determine that the user is standing. In the above example, the system may use a portion of the distance such as the vertical distance. By using vertical distance alone or in combination with an absolute distance (e.g., straight line distance between the two sensors), the system may further distinguish between when a user is lying down and standing up. For example, a lying down position may correspond to a very low vertical distance between the knee sensor and chest or waist sensor even though the absolute distance may be larger. A standing position may correspond to a larger vertical distance between the knee sensor and the waist or chest sensor but exhibit a similar absolute distance. In other examples, an angle formed by the various sensors may be used to determine an individual's position. Additionally or alternatively, the location of the user's various body parts may be evaluated in conjunction with accelerometer or movement data to determine if the user is exhibiting movement or (e.g., at, above or below) a specified level of movement.

In addition to deductions in activity points, the system may alert a user to inactivity to encourage active lifestyles. In one example, the system may alert the user by displaying a message or indicator on a device such as the wearable device assembly described herein after a specified amount of inactivity such as 2 minutes, 5 minutes, 30 minutes, 1 hour and the like. The amount of inactivity time may be additive over non-consecutive time periods. An amount of consecutive inactivity time may alternatively or additionally be tracked. For example, if the user is inactive between 10:15 and 11:00 AM and then again between 2:00 and 2:30 PM, the total amount of non-active time may be 1 hour and 15 minutes. The message or indicator of inactivity may be provided as a warning prior to deducting activity points. For example, the message may indicate that X amount of activity points will be deducted if the user does not exhibit a sufficient level of activity within a specified amount of time (e.g., 30 minutes, 5 minutes, 10 seconds, 30 seconds, 1 hour, 2 hours, etc.). Accordingly, the device may include an non-active timer to determine the amount of user non-activity. Additionally, the message may provide a suggestion as to a type of activity the user should perform to counter any risks introduced by the inactivity. For example, the system may suggest that the user walk 1 hour at a 10 minute mile pace. When the user has counteracted or accounted for the risks or negative effects of the detected amount of inactivity time, a celebratory message or other indication may be provided.

Warnings, point deductions and/or other notifications may be provided if a user returns to a sedentary or a non-active mode within a specified amount of time of exiting sedentary or a non-active mode. For example, the user may exercise or exhibit a sufficient level of activity to exit the sedentary or a non-active mode for a period of 10 minutes. However, the system or device may require at least **30** minutes of activity to avoid additional warnings for a period of time such as 1 hour, 2 hours, 3 hours, etc. For example, the warnings may indicate that the user did not exhibit activity for a sufficient amount of time or a sufficient level of activity or a combination thereof. Additionally, multiple sedentary periods within short amounts of time (e.g., a threshold amount of time) may require higher or additional levels of activity to counteract potential sedentary effects including health risks and the like. In a particular example, the user may be required to perform a higher level of activity to halt point deduction.

The device or other system may further advise a user as to an amount of non-active time allowed before negative health effects may occur. In one example, the device or system may include a countdown indicating a remaining amount of allowable non-active time before potential health risks may begin taking effect. An amount of permissible non-active time may be earned or accumulated based on an amount of activity performed. Accordingly, the device may also provide suggestions or recommendations as to a type and/or duration of activity that may be performed to earn a specified amount of non-active time (e.g., 1 hour of TV watching). Different types of non-active or sedentary activities may require different types or amounts of activity. For example, 1 hour of reclining may require more strenuous or longer exercise than 1 hour of sitting. In another example, 1 hour of sitting while knitting may require less strenuous or a lower amount of exercise or activity than 1 hour of sitting while watching television. According to one or more arrangements, recommendations may be generated based on empirical data and/or predefined programming and data tables specifying a type and/or duration of activity and a corresponding amount of permissible non-activity.

The device or activity tracking system may further recommend activities based on historical records. For instance, the device or tracking system may determine activity performed by the user in the past and generate recommendations based on those types of activities. Additionally or alternatively, the device or tracking system may generate recommendations for specific workouts performed by the user in the past. For example, a user may need to perform 500 calories worth of activity to counteract 2 hours of TV watching. In such a case, the system may recommend a particular workout performed by the user in the past in which the user burned 500 calories. Combinations of historical activity types and specific historical workouts may be used to generate recommendations. In one example, the system may recommend one of two workouts that the user has performed in the past based on a type of workout that the user appears to prefer. The preference may be determined based on a number of times the user has performed each type of workout. A workout or activity type may also be recommended based on location and time. For example, if a user previously performs a particular type of activity or a particular workout routine at the same location and/or at the same time, the system may recommend that type of activity or workout routine. Other recommendations algorithms and factors may be used.

System **100** may be configured to transmit energy expenditure points to a social networking website. The users may be ranked based on their total number of points for a desired time interval (e.g., rank by day, week, month, year, etc.).

3. Antenna for Wrist-Worn Sensor Assembly Device

Referring now to FIG. **5**, an exploded view of portions of the wrist-worn device **226** of FIG. **3** is shown. As seen in FIG. **5**, example implementations of the wrist-worn device **226** may include an outer over-mold member **502**, a flexible circuit member **504**, an internal spine member **506**, and an inner over-mold member **508**. The flexible circuit member **504** may be wrapped around the internal spine member **506**. The flexible circuit member **504** and internal spine member **506** assembly may be situated between the outer over-mold member **502** and the inner over-mold member **508**. The outer over-mold member **502** and the inner over-mold member **508** may thus form an outer encasement that encloses and protect the flexible circuit member **504** and the internal spine member **506**.

As noted above, flex areas **250** of the device **226** permit the device to flex as the device is wrapped around or removed from the wrist of a user. To facilitate the flexing of the device **226**, the outer over-mold member **502**, the flexible circuit member **504**, the internal spine member **506**, and the inner over-mold member **508** also include corresponding flex areas **250** as shown by way of example in FIG. **5**. In this example, the flex areas **250** are also located near the "shoulders" of the device components **506-508**.

The flexible circuit member **504** may be, for example, a flexible printed circuit board (FPCB or FPC). The flexible circuit member **504**, in this example, is wrapped around the internal spine member **506** of the device **226**. The flexible circuit member **504** is flexible enough to wrap around the spine member **506** of the device **226**, and also robust enough to survive the over-mold process and subsequent flexing in use. The flexible circuit member **504** may use rolled annealed copper on internal layers (with the grain along the long dimension of the flex), so as to provide superior wear characteristics. In some example implementations, high temperature elongation (HTE) electroformed copper foil—as well as any other types of copper foil that provide more elongation or ductile properties relative to cold rolled copper—may be selectively employed. Some or all of the repetitive flex areas **250** may have the copper on internal layers, e.g. so as to avoid weakening due to plating (which occurs on external layers) and/or to keep the copper closer to the neutral middle layer. Where the copper is on internal layers in these flex areas **250**, the outer solder mask may be removed since the outer solder mask may not be needed to protect such copper, and the solder mask may add to the stiffness of the flex (which added stiffness tends to be undesirable, e.g., where it promotes insufficient flex or otherwise impedes reaching sufficient flex). In one embodiment, all such copper is internal, such that all, substantially all, or some otherwise desirable group of outer solder masks are removed (e.g., select one or more may be retained to impart addition stiffness toward an optimal or desired flex). Additionally, to aid in survivability, one or more, or all junctions in the copper layer where acute or sharp angles would be formed (or otherwise where cracks might arise) may be filleted and rounded out to remove stress concentrations, e.g., toward preventing cracks. Examples of these places include junctions between traces and vias, traces and pads, and anywhere where a trace may make a change in direction. Lastly, where the over-molding operation has a penchant for inducing ripples (e.g., adjacent or otherwise by the USB connection of the FPC **504**), additional structures and methods are employed to improve the survivability of the FPC **504**.

As discussed above, the device includes an outer over-mold member **502** and an inner over-mold member **508** that collectively form an outer encasement. The outer over-mold member **502** and the inner over-mold member **504** may be an elastomer or polymeric member that is over-molded on to the flexible circuit member **504** mounted to the internal spine member **506**. There is a chance for crystals to be "crushed" or otherwise damaged, weakened or made infirm (e.g., so as to shorten life, retard performance, or the like) in the over-mold tool due to the extreme environment (e.g., high pressure). As an example, the metal can, which makes up the outside of the crystal (the actual crystal being housed within), might deform in the over-molding process. In one embodiment, crystal caps are used. By placing a crystal cap over a crystal and securing such cap with cyanoacrylate, the crystal (e.g., the crystal's top) may be protected (e.g., from any deformation). That is, by so placing crystal caps, the crystals operate after the over-mold operation.

As discussed further below, the device **226** may also include an antenna for wirelessly transmitting movement data obtained by the device to an electronic device. The antenna is designed and positioned in the device to enhance communication and operation. Since the device uses Bluetooth, the antenna efficiently transmits and receives associated RF signals. Because of the device configuration, however, certain constraints are present that impact the type of antenna that could be utilized in the device. The form factor is highly constrained, being thin and small. Additionally, the associated circuitry is to be over-molded with an elastomer/polymer member. Accordingly, in an exemplary embodiment, the antenna is enclosed within the device **226**. In some example implementations, the antenna may be embedded in the FPC **504** when the antenna is installed in the wrist-worn device **226**. Where the antenna is embedded in the flexible circuit member, the contour of the antenna may follow the contour of the flexible circuit member.

Various factors relating to the device **226** can affect the resonance of the antenna and the resulting radiation pattern. Refraction, reflection, absorption, and other pass loss effects can attenuate the power of the wireless signals that the antenna transmits. As an example, when the wrist-worn device **226** is wrapped around the wrist of a user—i.e., when the wrist-worn device receives the wrist of the user—the wrist or arm of the user may absorb the wireless signals the antenna transmits thereby attenuating the power of the wireless signals. Accordingly, the presence or absence of the wrist of the user is one factor that can affect the resonance and radiation pattern of the antenna of the wrist-worn device **226**.

Other factors that may affect the resonance and radiation pattern of the antenna may include the size of the antenna, the shape of the antenna, the location of the antenna within the body of the wrist-worn device **226**, the materials used to construct the wrist-worn device (e.g., the over-mold material, the electronic components, and the like), and the dimensions of the wrist-worn device itself. Modification of any of these factors may change the resonance and resulting radiation pattern of the antenna.

Accordingly, the antenna is designed and configured to generate a radiation pattern sufficient to wirelessly transmit the movement data to another electronic device despite any path loss that may occur. The designs and configurations of the example antennas described below may be employed to wirelessly transmit the movement data obtained by the device **226** to another electronic device such as, e.g., a computing device or another sensor assembly device worn by the user.

As noted above, the size, shape, and location of the antenna may affect the resonance and resulting radiation pattern of the antenna. In addition, the size of the wrist-worn device **226** itself may affect the resonance and radiation pattern of the antenna. For example, the antenna may be configured for installation in a wrist-worn device **226** having a relatively small size—e.g., approximately around 150-160 mm (5.91-6.30 in) in circumference; a relatively medium size—e.g., approximately around 180-190 mm (7.09-7.48 in) in circumference; or a relatively large size—e.g., approximately 200-210 mm (7.87-8.27 in) in circumference. In some example embodiments, a relatively small-sized wrist-worn device may be approximately around 158 mm (6.22 in) in circumference; a relatively medium-sized wrist-worn device may be approximately around 182 mm (7.17 in) in circumference; and a relatively large-sized wrist-worn device may be approximately around 206 mm (8.11 in) in circumference. It will be understood with the benefit of this disclosure that the wrist-worn device **226** may exhibit additional or alternative sizes. Accordingly, each different sized device may include a different antenna design and configuration due to the different placements of various metallic structures among the respectively sized devices.

For each size of the device **226**, the antenna may be designed and modeled using representative models of the electrical layout, the mechanical design, the materials being used, and a human wrist model. The antennas are designed such that they resonate at an off-peak resonant frequency generally associated with the device **226** alone, i.e., without a human wrist. As such, when a wrist is present, the antennas resonate at, close to or otherwise at a peak resonant frequency generally associated with the device **226**, e.g., a desired frequency. The resonant frequency at which performance of the antenna is optimal may be referred to as the peak resonant frequency. When the wrist of the user is not present (i.e., not received at) the device **226**, the off-peak resonant frequency may be slightly higher or slightly lower than the peak resonant frequency desired. In one embodiment, an automatic antenna optimization is present when the wrist is present. Automatic antenna optimization refers to the automatic shift from an off-peak resonant frequency when the wrist is not present at the wrist-worn device to a peak resonant frequency when the wrist is present at the wrist-worn device. In order to account for the presence of the wrist when wirelessly transmitting the movement data, the antenna may be tuned such that, when the wrist is not present, the antenna transmits at an off-peak resonant frequency and when the wrist is present, the off-peak resonant frequency shifts to the peak resonant frequency. In this way, the antenna may wirelessly transmit at the peak resonant frequency (i.e., at optimum performance) when the wrist is present at the wrist-worn device. In some example embodiments the peak resonant frequency may fall within the industrial, scientific, and medical (ISM) radio band. In other words, the antenna of the device **226** may operate at a peak resonant frequency between 2.4-2.5 GHz. In yet another embodiment, the antenna of the device **226** may operate at a peak resonant frequency between 2.40-2.48 GHz The design and the configuration of the antenna achieves optimum performance across the ISM band. In one embodiment, optimum performance may be defined as achieving a minimum of reflected power as defined by the measured **S11** parameter of the antenna.

As noted above, antennas having different designs and configurations may be respectively employed in relatively large-sized, medium-sized, and small-sized wrist-worn devices. FIGS. **6**A-B show an example of an implementation of an antenna **600** designed and configured for a relatively large-sized device **602**; FIGS. **8**A-B show an example of an implementation of an antenna **800** designed and configured for a relatively medium-sized device **802**; and FIGS. **10**A-B show an example of an implementation for an antenna **1000** designed and configured for a relatively small-sized device **1002**.

In the example implementations of antennas shown below, the antennas **600**, **800**, **1000** are positioned within the respective flex areas **250** of the respective wrist worn devices **602**, **802**, **1002**. In this way, interference and noise caused by the electronic components of the wrist-worn device (e.g., traces, vias, pads, LEDs, and the like) may be reduced. By positioning the antennas **600**, **800**, **1000** in the flex areas **250** of the respective wrist-worn devices **602**, **802**, **1002**, the antennas are located relatively far from the other electronic components of the wrist-worn devices. It will be understood with the benefit of this disclosure that an antenna may be positioned at alternative locations at the wrist-worn device so as to reduce noise and interference from the other electronic components.

Referring to FIGS. **6**A-B, an antenna **600** for a relatively large-sized wrist-worn device **602** is shown. As shown in this example, the antenna **600** is located within one of the flex areas **250** of the wrist worn device **602**. In this example, substantially all of the antenna **600** is located within the upper-right flex area **250** of the wrist worn device **602**. As noted above, the antenna **600** may be embedded in the flexible circuit member **504** and may therefore follow the contour of the flexible circuit member, for example, as the flexible circuit member dips through the flex area **250** of the wrist-worn device **602**. At its widest, the antenna may have a maximum width **604** of approximately around 3-4 mm (0.118-0.157 in), and in some example embodiments may have a maximum width of approximately around 3.4 mm (0.134 in). At its longest, the antenna may have a maximum length **606** of approximately around 19-20 mm (0.748-0.787 in), and in some example embodiments may have a maximum length of approximately around 19.88 mm (0.783 in).

The antenna **600**, in this example, includes a rounded end **608** and a pointed end **610** that is disposed or positioned opposite the rounded end. The antenna **600** also includes lateral edges, e.g., a left lateral edge **612** and a right lateral edge **614** that extend between the round end **608** and the pointed end **610** of the antenna. The right lateral edge **614**, in this example, includes a substantially straight edge portion **616** extending between the rounded end **608** and the pointed end **610**.

The left lateral edge **612** of the antenna **600**, in this example, includes a substantially straight edge portion **618** positioned proximate to the rounded end **608** and a sloped edge portion **620** positioned proximate to the pointed end **610**. In this example, the straight edge portion **618** and the sloped edge portion **620** meet near the middle **622** of the antenna **600**. The sloped edge portion **620** slopes away from the straight edge portion **618** toward the pointed end **610** such that the width of the antenna tapers between the middle **622** of the antenna and the pointed end **610** as shown by way of example in FIG. **6**.

The design and configuration of the antenna **600** in FIGS. **6**A-B may produce the radiation pattern **700** shown in FIG. **7**. As seen in FIG. **7**, the antenna **600** may produce the radiation pattern **700** when the wrist **702** of the user is received at the wrist-worn device **602**. The radiation pattern **700** shown in FIG. **7** may successfully transmit wireless signals containing the movement data obtained by the wrist-worn device **602** to another electronic device. The radiation pattern **700** in FIG. **7**, illustrates the relative gain (dB) of the wireless signals at various regions surrounding the wrist-worn device **602**. Relatively warm areas of the radiation pattern **700** identify regions where relatively more gain is observed while relatively cool areas of the radiation pattern identify regions where relatively less gain is observed. In this regard, the design and the configuration of the antenna **600** produce a radiation pattern **700** where the relatively higher gain areas **704** are directed away from the body of the user. In this way, the design and configuration of the antenna **600** advantageously increases the likelihood that the wireless signals will reach the desired electronic device and decreases the likelihood that the wireless signals will be absorbed or otherwise attenuated by the body of the user.

Referring now to FIGS. **8**A-B, an antenna **800** for a relatively medium-sized wrist-worn device **802** is shown. The antenna **800** in this example is similarly located within one of the flex areas **250** of the wrist worn device **802**, e.g., the upper-right flex area. As noted above, the antenna **800** may be embedded in the flexible circuit member **504** and may therefore follow the contour of the flexible circuit member, for example, as the flexible circuit member dips through the flex area **250** of the wrist-worn device **802**. At its widest, the antenna may have a maximum width **804** of approximately around 5-6 mm (0.197-0.236 in), and in some example embodiments may have a maximum width of approximately around 5.43 mm (0.214 in). The antenna **800**, in this example, may also be relatively narrower near the middle **806** of the antenna. Near the middle **806**, the antenna **800** may have a width **808** of approximately around 3-4 mm (0.118-0.157 in), and in some example embodiments may have a middle width of around 3.29 mm (0.130 in). At its longest, the antenna may have a maximum length **810** of approximately around 22-23 mm (0.866-0.906 in), and in some example embodiments may have a maximum length of approximately around 22.77 mm (0.896 in).

The antenna **800**, in this example, also includes a rounded end **812** and a pointed end **814** disposed or positioned opposite the rounded end. The antenna also includes a left edge **816** and a right lateral edge **818** that extend between the rounded end **812** and the pointed end **814** of the antenna. The right lateral edge **818**, in this example, includes a substantially straight edge portion **820** that extends between the rounded end **812** and the pointed end **814**. The left lateral edge **816** of the antenna **800**, in this example, includes a substantially straight upper edge portion **822**, a substantially straight middle edge portion **824**, and a sloped lower edge portion **826**. As seen in FIG. **8**B, the straight middle edge portion **824** is offset from the straight upper edge portion **822**. Accordingly, the antenna **800** also includes a curved edge portion **828** positioned between and connecting the straight upper edge portion **822** and the straight middle edge portion **824**. The curved edge portion **828** of the left lateral edge **816**, in this example, exhibits an S-shape such that the left later edge curves inward toward the antenna **800** between the straight upper edge portion **822** and the middle edge portion **824**. The sloped edge portion **826** and the straight middle edge portion **824** meet near the middle **806** of the antenna **800** in this example. the sloped edge portion **826** slopes away from the straight middle edge portion **824** toward the pointed end **814** such that the width of the antenna tapers between the middle **806** of the antenna and the pointed end **814** as shown by way of example in FIG. **8**.

The design and configuration of the antenna **800** in FIGS. **8**A-B may produce the radiation pattern **900** shown in FIG. **9**. As seen in FIG. **9**, the antenna **800** may produce the radiation pattern **900** when the wrist **902** of the user is received at the wrist-worn device **802**. The radiation pattern **900** shown in FIG. **9** may successfully transmit wireless signals containing the movement data obtained by the wrist-worn device **802** to another electronic device. The radiation pattern **900** in FIG. **9**, illustrates the relative gain (dB) of the wireless signals at various regions surrounding the wrist-worn device **802**. Relatively warm areas of the radiation pattern **900** identify regions where relatively more gain is observed while relatively cool areas of the radiation pattern identify regions where relatively less gain is observed. Similar to FIG. **7**, the radiation pattern

900 produced by the antenna **800** advantageously directs the relatively high gain areas **904** away from the body of the user.

Referring now to FIG. **10**, an antenna **1000** for a relatively small-sized wrist-worn device **1002** is shown. The antenna **1000** in this example is likewise located within one of the flex areas **250** of the wrist worn device **1002**, e.g., the upper-right flex area. As noted above, the antenna **1000** may be embedded in the flexible circuit member **504** and may therefore follow the contour of the flexible circuit member, for example, as the flexible circuit member dips through the flex area **250** of the wrist-worn device **1002**. At its widest, the antenna **1000** may have a maximum width **1004** of approximately around 3-4 mm (0.118-0.157 in), and in some example embodiments may have a maximum width of approximately around 3.54 mm (0.139 in). At its longest, the antenna may have a maximum length **1006** of approximately around 12-13 mm (0.472-0.512 in), and in some example embodiments may have a maximum length of approximately around 12.6 mm (0.496 in).

As seen in this example, the antenna **1000** for the relatively small-sized wrist worn device **1002** includes multiple substantially linear antenna portions **1008-1020** that are disposed at an angle relative to one another such that the antenna **1000** exhibits or defines a jagged shape. In this example shown in FIGS. **10**A-B, the antenna **1000** includes seven linear antenna portions, and a first linear antenna portion **1008** is contiguous with a second linear antenna portion **1010**; the second linear antenna portion **1010** is also contiguous with a third linear antenna portion **1012**; the third linear antenna portion **1012** is contiguous with a fourth linear antenna portion **1014**; the fourth linear antenna portion **1014** is contiguous with a fifth linear antenna portion **1016**; the fifth linear antenna portion **1016** is contiguous with a sixth linear antenna portion **1018**; and the sixth linear antenna portion is contiguous with a seventh linear antenna portion **1020**.

The first linear antenna portion **1008** and the second linear antenna portion **1010** are disposed at an angle relative to one another to form one of six V-shaped sections **1022-1032** of the antenna **800**. The other five V-shaped sections **1024-1032** of the antenna **800** are respectively formed by the second and third linear antenna portions **1010** and **1012**, the third and fourth linear antenna portions **1012** and **1014**, and the fourth and fifth linear antenna portions **1014** and **1016**, the fifth and sixth linear antenna portions **1016** and **1018**, and the sixth and seventh linear antenna portions **1018** and **1020**, which are similarly disposed at an angle relative to one another. The V-shaped sections **1022-1032** of the antenna **800** may point in opposite directions, e.g., toward the front **1034** of the wrist-worn device **1002** or toward the rear **1036** of the wrist-worn device. In this example, the first, third, and fifth V-shaped sections **1022**, **1026**, and **1030** point toward the front **1034** of the wrist-worn device **1002**, and the second, fourth, and sixth V-shaped sections **1024**, **1028**, and **1032** point toward the rear **1036** of the wrist-worn device **1002**.

The design and configuration of the antenna **1000** in FIGS. **10**A-B may produce the radiation pattern **1100** shown in FIG. **11**. As seen in FIG. **11**, the antenna **1000** may produce the radiation pattern **1100** when the wrist **1102** of the user is received at the wrist-worn device **1002**. The radiation pattern **1100** shown in FIG. **11** may successfully transmit wireless signals containing the movement data obtained by the wrist-worn device **1002** to another electronic device. The radiation pattern **1100** in FIG. **11**, illustrates the relative gain (dB) of the wireless signals at various regions surrounding the wrist-worn device **1002**. Relatively warm areas of the radiation pattern **1100** identify regions where relatively more gain is observed while relatively cool areas of the radiation pattern identify regions where relatively less gain is observed. Similar to antennas **600** and **800** above, the antenna **1000** likewise produces a radiation pattern **1100** where the relatively high gain areas **1104** are directed away from the body of the user thereby advantageously minimizing or avoiding absorption or other attenuation of the wireless signals.

It will be understood with the benefit of this disclosure that additional or alternative antenna designs and configurations may be selectively employed to achieve a radiation pattern sufficient to wirelessly transmit the movement data from the antenna of the wrist-worn device to another electronic device. The particular antenna designs and configurations employed may be influenced by the path loss effects observed as a result of the particular design of the wrist-worn device. It will also be understood that the discussions above are applicable to sensory accessory devices worn at alternative locations on the user, e.g., an arm-worn device worn on the arm of the user, an ankle-worn device worn on the ankle of the user, and so on.

These features can be combined with the several other features described herein as desired.

5. Conclusion

Providing an activity environment having one or more of the features described herein may provide a user with an experience that will encourage and motivate the user to engage in athletic activities and improve his or her fitness. Users may further communicate through social communities and challenge one another to participate in point challenges.

Aspects of the embodiments have been described in terms of illustrative embodiments thereof. Numerous other embodiments, modifications and variations within the scope and spirit of the appended claims will occur to persons of ordinary skill in the art from a review of this disclosure. For example, one of ordinary skill in the art will appreciate that the steps illustrated in the illustrative figures may be performed in other than the recited order, and that one or more steps illustrated may be optional in accordance with aspects of the embodiments.

What is claimed is:

1. A wrist-worn device that monitors movements of a user comprising:

a sensor assembly configured to detect movement of the user and generate sensor data based on the movement detected;

a controller connected to the sensor assembly that obtains movement data based, at least in part, on the sensor data; and

an antenna connected to the controller that is configured to operate at a desired frequency when a wrist of the user is received by the device such that the movement data is wirelessly transmittable from the wrist-worn device to an electronic device;

wherein the desired frequency is a peak resonant frequency, the antenna is tuned such that the antenna operates at an off-peak resonant frequency relative the peak resonant frequency when the wrist is not received by the wrist-worn device, and the antenna produces a radiation pattern having relatively high gain areas that are directed away from a body of the user when wirelessly transmitting the movement data;

wherein a body of the wrist-worn device includes a plurality of flex areas and the wrist-worn device further comprises

an internal spine member extending through the body of the wrist-worn device, and a flexible circuit member wrapped around and connected to the spine member, the flexible circuit member interconnects the controller and one or more sensors of the sensor assembly; and

wherein the antenna is connected to the flexible circuit member and at least a portion of the antenna is located in one of the flex areas of the body of the wrist-worn device.

2. The wrist-worn device claim **1** wherein substantially all of the antenna is located in one of the flex areas of the body of the wrist-worn device.

3. The wrist-worn device of claim **1** wherein the antenna is embedded in the flexible circuit member.

4. The wrist-worn device of claim **3** wherein the antenna includes:

a rounded end;

a pointed end disposed opposite the rounded end; and

a first lateral edge extending between the rounded end and the pointed end, the first lateral edge having a first substantially straight edge portion that extends between the rounded end and the pointed end.

5. The wrist-worn device of claim **4** wherein the antenna further includes:

a second lateral edge disposed opposite the first lateral edge and extending between the rounded end and the pointed end, the second lateral edge having a second substantially straight edge portion proximate to the rounded end and a sloped edge portion proximate to the second substantially straight edge portion that slopes away from the second substantially straight edge portion toward the pointed end.

6. The wrist-worn device of claim **5** wherein the antenna has a maximum length of approximately 19-20 millimeters and a maximum width of approximately 3-4 millimeters.

7. The wrist-worn device of claim **6** wherein a circumference of the wrist-worn device is approximately 200-210 millimeters.

8. The wrist-worn device of claim **4** wherein the antenna further includes:

a second lateral edge disposed opposite the first lateral edge and extending between the rounded end and the pointed end, the second lateral edge having a second substantially straight edge portion proximate to the rounded end, a curved edge portion connecting the second substantially straight edge portion to a third substantially straight edge portion, and a sloped edge portion proximate to the pointed end that slopes away from the third substantially straight edge portion toward the pointed end.

9. The wrist-worn device of claim **8** wherein the antenna has a maximum length of approximately 22-23 millimeters and a maximum width of approximately 5-6 millimeters.

10. The wrist-worn device of claim **9** wherein a circumference of the wrist-worn device is between around 180-190 millimeters.

11. The wrist-worn device of claim **3** wherein the antenna includes a plurality of substantially linear antenna portions disposed at an angle relative to one another such that the antenna defines a jagged shape.

12. The wrist-worn device of claim **11** wherein the plurality of substantially linear antenna portions includes seven substantially linear antenna portions and wherein:

a first linear antenna portion and a second liner antenna portion define a first V-shaped section of the antenna such that the first V-shaped section points toward a first direction;

the second linear antenna portion and a third linear antenna portion define a second V-shaped section of the antenna such that the second V-shaped section points toward a second direction opposite the first direction;

the third linear antenna portion and a linear fourth antenna portion define a third V-shaped section of the antenna such that the third V-shaped section points toward the first direction;

the fourth linear antenna portion and a fifth linear antenna portion define a fourth V-shaped section of the antenna such that the fourth V-shaped section points toward the second direction;

the fifth linear antenna portion and a sixth linear antenna portion define a fifth V-shaped section of the antenna such that the fifth V-shaped section points toward the first direction; and

the sixth linear antenna portion and a seventh linear antenna portion define a sixth V-shaped section of the antenna such that the sixth V-shaped section points toward the second direction.

13. The wrist-worn device of claim **12** wherein the antenna has a maximum length of approximately 12-13 millimeters and a maximum width of approximately 3-4 millimeters.

14. The wrist-worn device of claim **13** wherein a circumference of the wrist-worn device is between around 150-160 millimeters.

15. An antenna for a wrist-worn device that monitors movements of a user comprising:

an antenna configuration that causes the antenna to operate at a desired frequency when a wrist of the user is received by the device such that movement data collected by the wrist-worn device is wirelessly transmittable to an electronic device;

wherein the antenna configuration causes the antenna to produce a radiation pattern having relatively high gain areas that are directed away from a body of the user when wirelessly transmitting the movement data; and

wherein the antenna is configured to be embedded in a flexible circuit member of the wrist-worn device when installed in the wrist-worn device such that at least a portion of the antenna is positioned in a flex area of the wrist-worn device when embedded in the flexible circuit member.

16. The antenna of claim **15** wherein the antenna is configured to be installed in a wrist-worn device having a circumference of approximately 200-210 millimeters, and wherein the antenna configuration includes:

a rounded end;

a pointed end disposed opposite the rounded end;

a first lateral edge extending between the rounded end and the pointed end, the first lateral edge having a first substantially straight edge portion that extends between the rounded end and the pointed end; and

a second lateral edge disposed opposite the first lateral edge and extending between the rounded end and the pointed end, the second lateral edge having a second substantially straight edge portion proximate to the rounded end and a sloped edge portion proximate to the second substantially straight edge portion that slopes away from the second substantially straight edge portion toward the pointed end.

17. The antenna of claim **15** wherein the antenna is configured to be installed in a wrist-worn device having a circumference of approximately 180-190 millimeters, and wherein the antenna configuration includes:

a rounded end;

a pointed end disposed opposite the rounded end;

a first lateral edge extending between the rounded end and the pointed end, the first lateral edge having a first substantially straight edge portion that extends between the rounded end and the pointed end; and

a second lateral edge disposed opposite the first lateral edge and extending between the rounded end and the pointed end, the second lateral edge having a second substantially straight edge portion proximate to the rounded end and a sloped edge portion proximate to the second substantially straight edge portion that slopes away from the second substantially straight edge portion toward the pointed end.

18. The antenna of claim **15** wherein the antenna is configured to be installed in a wrist-worn device having a circumference of approximately 150-160 millimeters, and wherein the antenna configuration includes:

a plurality of substantially linear antenna portions disposed at an angle relative to one another such that the antenna defines a jagged shape.

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